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Beginner's Guide to Small Animal Anesthesia, Sedation, & Analgesia in General Practice

Written by Benjamin Pritzker

Beginner's Guide to Small Animal Anesthesia, Sedation, & Analgesia in General Practice

An integrated approach to the theory and practice of anesthesia, analgesia, sedation, and physiological principles in small animal general practice.

Benjamin L. Pritzker

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Preface

Growing up on a farm, I, like most others in Veterinary Medicine, had an ingrained love for animals. I was surrounded by animals all throughout my childhood. From riding horses to tending chickens, interactions with animals made up most of my day. From a young age, I had a deep understanding of animal welfare and husbandry. When I was 9 years old, I got my first job (yes, in 2013). Getting paid under the table at an exotic animal and fish store, sometimes my payment consisted of exotic pets. My parents would cringe in anticipation when picking me up from my 10-hour shift, wondering what unearthly creature I wanted to bring home that day. Animal husbandry and hobbying engulfed my young mind before I reached double digits. By age 10 years old, I had my first successful agricultural business; I bred and sold dozens of rabbit breeds. It started with one rabbit I took home from work and quickly turned to an obsession. Soon, I had over 40 rabbits in my parents barn. "Breed like rabbits" is an understated expression. I was producing over 50 baby rabbits a month. Some I sold wholesale to the exotic pet store I still worked at, and some I offered privately to local families.

Once I turned 11, my animal obsession had gotten less fluffy and more scaly. I began to downsize my rabbit collection and turned to a more sophisticated group of animals—reptiles. It started with a Bearded Dragon, a benign, cute, and friendly pet lizard. Very quickly, my childhood bedroom was overcome with cages, terrariums, and reptile boxes. The heat and humidity required for my collection made my room inhospitable to sleep in—so much so that I took over the family room (with 4 other people at home) for over 15 months so I could sleep in normal conditions. Only 13 years old, I had over 50 snakes (Ball Pythons, Corn Snakes, King Snakes, Hognose, Boa Constrictors, and more), over 30 lizards (Leopard Geckos, Bearded Dragons, and Crested Geckos), and dozens of other reptiles, including tortoises, turtles, and monitor lizards. Breeding and selling was my bread and butter, but rescuing and rehoming also captured my interest.

As one can imagine, this was an expensive hobby. I would use the couple hundred dollars I made from the pet store to pay for mice, rats, and insects for my collection. Soon, it got to be too expensive as my collection only grew. I decided I needed to grow my own feeders for my reptiles. This

included mice, rats, crickets, and mealworms. Within 10 days of this idea, I had built a fully functioning feeder growing room in my barn. Much like all of my other animal hobbies, growing feeder species proved profitable. I began to produce so many mice, rats, and insects that I started supplying the store where I worked. I was not only able to feed my own collection but also made an additional five hundred dollars per month simply selling feeders.

By age 14, my passion for animals turned into a profitable business. My reptile collection grew out of my bedroom. My father and I built a $10,000 reptile breeding room—complete with climate control, humidity control, and floor-to-ceiling reptile cages. I turned an old Pepsi fridge into a giant incubator. I opened an ecommerce website where my customers could purchase the freshly hatched snakes and lizards. Not even 15, I was bringing in over $5,000 a month. The only problem was my sense of budgeting. Unsurprisingly, a 14 year old is probably not the best with money. My parents helped me save some of my money. But ultimately, the majority of the money I was making was going right back to more breeding adults, new cages, and more supplies for my business. At age 15, I made the last-minute decision to go to a liberal arts boarding school for high school. Although the school offered to build a snake breeding facility, I declined and decided it was time to focus on turning my passion (and former business) into a career.

My first interaction with Veterinary Medicine was the farm visits our Veterinarian would make. I was young, around 10 or 11. I remember marveling at the way she could effortlessly (and seemingly randomly) stick a needle in a mini-horse's neck and collect blood. She could do everything from vaccinating our baby goats to castrating our donkeys. Although interesting, my passion for animal hobbying trumped my interest in medicine. I didn't take a direct interest in veterinary medicine until I was 14. While still breeding and selling reptiles, I decided to shadow a family friend who happened to be a veterinarian at a large dog and cat hospital in northern New Jersey. From the moment I walked through the door, there was no going back.

Since I was only 14 (and had pink hair), all of the middle-aged techs loved me. I remember them telling me all about the drugs they were administering, the vaccines they were giving, and the surgeries they were helping with. At age 14, I saw the good, the bad, and the ugly of veterinary medicine. I saw my first euthanasia within 2 hours of my externship. Without prompting, I saw that euthanasia as freeing, compassionate, and beautiful. Coming from a background of farm life, animal death was

something I knew all too well. But to see a professional render death peacefully and painlessly was trajectory-changing. Watching surgery unlocked a feeling of awe, a feeling of disbelief—to open the abdominal cavity of a dog, a creature we knew next to nothing about only a couple hundred years ago, was simply incredible. The shimmer of the surgeon's scalpel blade captured my eye as she made the cuts into the dog's belly. Only 20 minutes later, she removed what looked like a worm, and just like that, the dog was spayed. After those transformative 2 weeks of externing, I knew where my real passion with animals lay, not in their everyday care, but at their worst moments. I wanted to be there for a family when their pet needed it most; I wanted to be the one to save that cat; I *needed* to be the one holding that scalpel.

During the pandemic, my family and I moved to a more rural part of New Jersey where we built our dream *farmette*. We began using a new vet, as our old one was now too far. This vet took a liking to me, and me to her. Within 2 weeks of her initial visit to treat my donkey's laminitis, I was riding along in her truck. I visited farm after farm with her—each offering something different. I helped with castrations, dentals, sewing up baby sheep after getting into fights with goats… I went from liking Veterinary Medicine to being obsessed. I yearned for more knowledge every day. Counting down the days until I could apply to vet school, I got a job as a Veterinary Assistant at my large animal vet's mixed-practice clinic. That is where it all started. That 3 exam room hospital lit the fire in me that's going to drive me to my DVM.

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I do not consider myself an expert; rather, I am an enthusiastic undergraduate student with a strong academic focus in physiology, biochemistry, and pharmacology. My current research centers on neuropharmacology and its applications in pain management, neurodegenerative diseases, and addiction. Through this work, I have discovered a compelling niche within veterinary medicine that has deeply resonated with me. Over the past three years, I have gained substantial experience in the principles and practice of anesthesia administration and management.

This interest has been greatly nurtured by the mentorship of Dr. Jeffrey Salatiello, Dr. MaryBeth Hamorski, Dr. Ruth Martin, and Dr. Heather Loesner, with whom anesthesia has consistently been a central topic of discussion. I have also been fortunate to engage in hands-on learning within specialty hospitals, working alongside board-certified

anesthesiologists and Veterinary Technician Specialists. While experiential learning has been invaluable, textbooks and scientific literature have served as essential tools in broadening my understanding and introducing me to evolving protocols and techniques.

Anesthesiology has become a clear area of professional interest, one that I intend to pursue further. In the meantime, I aim to share the foundational knowledge and practical insights I have found most beneficial within general practice settings. As someone still early in their career, I hope this "Beginner's Guide" serves others the way I wish such a resource had been available to me when I first started.

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Starting in an industry that requires training, yet said training is almost always inaccessible, is hard. When I first became a Veterinary Assistant in anesthesia/surgery, I was like a fish out of water. In any other industry, there would be support and planned education in place. In veterinary medicine, that's almost never the case; and through no major fault of individual staff but instead the institution of education. Learning on the job is never easy, especially when it comes to complex and academic-heavy topics like anesthesia and surgery. Ever since I stepped foot in an OR, I've been in love with the organized chaos and the rush that it brings. Specifically, the practice of anesthesia excites me. In my mind, anesthesia is total control of every body system, every function, and the entire patient. The surgeon is responsible for a specific task, while the anesthetist is responsible for keeping the patient alive. While I am not trying to compare apples to oranges, anesthesia—much like surgery—is an art, one that takes time, skill, and knowledge. This handbook is meant to be a guide for those like me—new, excited, frustrated—who yearn to learn more.

Most of my anesthesia experience comes from a general practice setting. Anesthesia overlaps with many other disciplines, including emergency and critical care. It is important to note this guide is strictly focusing on methods and concepts I feel are valuable for a beginner to understand in a general practice setting. While I do cover some non-elective cases, those wishing to learn more about Emergency/ Critical Care (ECC) anesthesia should refer to additional resources.

Please note, the material in this handbook builds on basic anatomy and physiology. This book is a mix of pharmacology pathways, physiologic principles, and clinical applications while also providing everything I wish I had at my fingertips when I was first introduced to anesthesia. While it is important to read accredited textbooks and references, this is a simpler and

boiled-down version of my findings in practice. As mentioned previously, please ensure competency in anatomy and physiology prior to using this guide. Also note that this book assumes the anesthetist has mastered fundamental clinical skills such as IV catheter placement, intubation, and overall surgical nursing.

This handbook only refers to feline and canine patients in the general practice setting.

Author's Note on Butorphanol as an Analgesic in Small Animal Practice

When it comes to analgesia, every practitioner has their preferences. It is becoming increasingly clear that, in a clinical setting, butorphanol does not provide adequate analgesia in dogs and cats for most, if not all, surgical procedures. Butorphanol is a well-known opioid and widely used in practice due to its strong sedative effects without producing dysphoria, vomiting, and significant hemodynamic changes. Butorphanol is an agonist/antagonist opioid; it agonizes the kappa-opioid receptor (KOR) and potentially the delta-opioid receptor (DOR) while antagonizing the mu-opioid receptor (MOR). The KOR and DOR provide a lesser intracellular response when stimulated compared to the mu-opioid receptor. New data is showing its analgesic effect is poor and only lasts 29-47 minutes.[1,2] Studies show that NSAIDs (generally regarded as a less powerful analgesic class) are more effective against somatic and visceral pain than butorphanol.[21] Butorphanol antagonizes the MOR for up to 8 hours,[9] although the author and contributors of this book notice a 1-2 hour clinically significant period of antagonism. This means that any concurrent or subsequent full-mu agonist (e.g., hydromorphone) may not exhibit its full effect on the MOR, decreasing analgesia.

That being said, butorphanol does have a place in modern practice but not as a strong analgesic. Butorphanol is a strong and safe sedative that can be utilized in various cocktails to produce various levels of sedation. Butorphanol may also reduce Fear, Anxiety, and Stress (FAS) associated with hospitalization. Its use as a sedative proves useful in acute respiratory distress. Depending on etiology and specifics of the present illness, oftentimes in respiratory distress, increased and forceful ventilation causes extremely turbulent airflow in the respiratory tree. In cases of dynamic airway obstruction (i.e. brachycephalic, tracheal/laryngeal masses, or tracheal collapse), turbulent high velocity air movement can worsen airway collapse. Butorphanol works to lightly sedate the patient to allow for

calmer and lower velocity breaths. To that point, butorphanol should rarely be used as an analgesic for patients in pain. While butorphanol may provide sufficient analgesia for short, minimally painful procedures, it should generally be avoided in surgical cases unless other modalities of analgesia are being implemented (i.e. locoregional anesthesia and/or analgesic CRI's,). Examples of cases where butorphanol is an appropriate opioid to select include minor laceration repairs, sedated splinting/bandaging, sedated radiographs, and nail trims, as well as to reduce fear, anxiety, and stress associated with hospitalization. Some suggest butorphanol's use in true prophylactic dental procedures (i.e., with no extractions).

While butorphanol does provide adequate analgesia for prophylactic dental procedures, it can be difficult to anticipate the degree of dental disease and the number of extractions until under general anesthesia and full-mouth radiograph. As mentioned previously, butorphanol administration can decrease analgesia of full-mu agonist opioids for up to 8 hours. If the patient does need extractions, it may receive inadequate analgesia. For this reason, in my clinical understanding, butorphanol should be avoided in most, if not all, dental procedures, even those with no anticipated extractions.

Chapter 1
Creating an Anesthesia/Analgesia Plan

Preparation is the cornerstone of safe anesthesia. Creating an anesthesia/analgesia (A/A) plan allows the anesthetist to assess patient risk, anticipated pain levels, and potential complications. Preparing an A/A plan is the best way to mitigate medication errors, pharmacologic complications, and overall under-preparedness. There are several important aspects of a high-quality A/A plan. However, even once mastered on paper, the anesthetist must learn through experience. In veterinary anesthesia, we have the privilege to work on several different species. Besides differences in species, every patient will handle anesthesia and drugs differently. Interpatient variability in responses to drugs can make predicting responses challenging. This is why it is prudent to have an individualized "plan A" as well as contingency plans. A skilled anesthetist must anticipate every complication and have the ability to adapt to changes and troubleshoot complications. Flexibility and vigilance will allow an anesthetist to grow greatly in this industry. A/A plans must also be multimodal, which describes a technique of using low doses of drugs with different mechanisms to achieve the same or better effect while minimizing any adverse effects and risks. Note that anesthesia and analgesia go hand-in-hand; safe anesthesia cannot be delivered without adequate analgesia (for painful procedures). Anesthesia involves several components including unconsciousness, amnesia, immobility, analgesia, and a state of reversible autonomic nervous system depression. The key to multimodal anesthesia is the ability to target each of these components with a single agent (i.e. high concentration of inhalant) or multiple agents to specifically target each of these components. Even if general anesthesia is not indicated, an A/A plan is still best practice for procedural sedation. Finally, note that this section is not meant to provide information regarding specific drugs and their usage but rather to offer a general idea of when and how to use classes of medications.

"There are no safe anesthetic agents, there are no safe anesthetic procedures. There are only safe anesthetists." Robert Smith, MD

Components of an Effective and Safe Anesthesia &

Analgesia Plan

To ensure patient comfort and safety, every anesthesia/analgesia (henceforth referred to as "A/A" for consistency) plan must include various aspects. Some relate more to comfort, while others ensure safety in cases of complications. There are three important safety aspects of an A/A plan: (1) qualified personnel/monitoring, (2) vascular access, and (3) airway management. Firstly, competent and skilled personnel must monitor every patient receiving an anesthetic or analgesic. Monitoring is one of the most, if not the most, important aspects of anesthesia. Any individual administering a medication must know the Five Rights of Medication: (1) indications (when is this drug used), (2) mechanism of action (how the drug works), (3) onset and duration of action (how long and how quickly the drug works), (4) contraindications (cases in which the drug should not be used), and (5) side effects and responses (what effects does the drug produce and how will that be managed if problematic [e.g., vomiting from opioids; antiemetics being the management]). Part of monitoring A/A is assessing pain levels. Adequate analgesia is required in every phase of high-quality-anesthesia.

Besides competent personnel, one of the first steps of creating an A/A plan is planning for anticipated complications. This can be further distinguished into 3 categories: (1) patient factors (i.e. signalment and morbidities), (2) procedural factors (i.e.. risk of hemorrhage and volume loss, vascular occlusion, etc.), (3) pharmacological factors (desired and undesired effects of drugs). Age, breed, and sex may all inform how the body processes drugs and responds to anesthesia. Knowledge of the procedure, anticipated pain levels, and potential complications is prudent to appropriately plan. Generally, the anesthetist should have knowledge about present illnesses a patient may have and their pertinent effects on anesthesia. Before the patient is anesthetized, the anesthetic should have pre-calculated emergency drugs and supportive drugs that are likely to be administered in the event of a complication.

In most cases, the A/A plan should include intravenous access of some sort. The anesthetist must always analyze the risks and benefits of obtaining vascular access including time, resources, patient stress, and skill. In everyday clinical small animal practice, vascular access is highly recommended in most, if not all anesthetized patients. There are several methods to obtain vascular access, including peripheral intravenous (IV) catheters, central lines, and interosseous (IO) catheters. At least one of these methods is required *no matter what* for every patient. Most patients,

especially in a general practice setting, will receive a peripheral IV catheter as they are relatively easy to place and maintain. Even if the patient is not receiving any IV medications, an IV catheter ensures immediate access if needed urgently. For example, a young cat with low anesthetic risk who received IM Kitty Magic for induction still requires an IV catheter in case of emergency. An IV catheter allows for quick, emergent administration of rescue drugs and fluids.

Proper airway management is important to prevent hypoxemia and subsequent negative effects. This may range from flow-by oxygen to intubation. In general, most, if not all, anesthetized or sedated patients should receive supplemental oxygen in the indicated fashion. In some cases of minor or short procedures, an endotracheal tube (ETT) may not be indicated. However, even in this case, the patient must still receive oxygen. If not delivered via ETT, oxygen can be provided via flow-by, face mask, nasal prongs, or nasal cannula. Most anesthetic agents alter cardiac output and the carrying capacity of hemoglobin therefore affecting the delivery of oxygen to tissues. Additionally, any natural compensatory mechanisms of the body may be suppressed while under general anesthesia. The effect of providing supplemental oxygen is to resist change against these alterations and increase oxygen reserved in the lungs. Pre-oxygenation is a technique in which supplemental oxygen is supplied 3-5 minutes prior to induction of anesthesia which raises the body's tolerance to post-induction hypoventilation or apnea. Ideally, this should be performed in every patient whenever hypoventilation or respiratory depression is a potential side effect of the anesthetic agents used. In situations where patients become agitated with use of a face mask, flow-by oxygen can be substituted until the patient becomes more compliant to the use of face mask with additional sedation.

Lastly, multimodal A/A plans are the most safe and effective way to administer anesthesia and analgesia. Multimodality refers to the practice of implementing several different mechanisms to achieve the same or better effect as compared to using one mechanism. For example, historically, dogs undergoing castration usually received one preoperative dose of an opioid; this opioid dose was usually very high and brought some undesirable effects. Using a multimodal technique, one can employ the use of local anesthetics, non-steroidal anti-inflammatory drugs (NSAIDs), and subsequently greatly reduce opioid requirements which decreases side effects from said opioid.

The Anesthesia Care Continuum

The Anesthesia Care Continuum is a theory that describes the

totality of anesthetic care and management. There are four distinct phases of anesthesia: (1) preoperative, (2) induction, (3) intraoperative/ maintenance, and (4) recovery/ postoperative [**Table 1**]. Each phase has specific needs and goals all aimed at patient safety, patient comfort, and staff safety. Monitoring the patient is vital in each phase and more important in some than others. Before any A/A drugs can be selected, the anesthetist (or attending provider) must do a preoperative assessment of the patient.

Phase	Goals	Specific Actions	Examples
Preoperative	Assess and minimize anesthetic risk, prepare for at-home care, prepare plan A, B, C, D…, relieving anxiety, prophylactically treating pain.	Fasting (usually >6 hours); preoperative work-up, providing pre-op medications. .	At-home oral sedatives (Gabapentin, Trazodone), antiemetics, opioids, benzodiazepines, NSAIDs*, tranquilizers/sedatives (DexDomitor or Acepromazine).
Induction	Render unconsciousness with minimal changes to normal physiology.	Multimodal approach to induction, secure airway (if indicated), monitor hemodynamics, minimize time until cutting.	Propofol, Etomidate, Alfaxalone, Midazolam, Ketamine, Telazol and sometimes opioids.
Intraoperative/ Maintenance	Maintain balanced anesthesia with minimal changes to normal physiology. Troubleshoot complications and reassess A/A plan as needed.	Utilize parietal intravenous anesthesia (PIVA) CRI's to minimize inhalant requirements,[23] propofol CRI as total intravenous anesthesia (TIVA), give sedative/analgesic boluses PRN, provide intravenous fluids, monitor hemodynamic and metabolic status.	Opioid/Lidocaine/Ketamine CRI, propofol CRI, benzo CRI, isoflurane/sevoflurane maintenance, crystalloid IV fluids.
Recovery/ Postoperative	Ensure calm and pain-free recovery and at-home transition and recovery.	Monitor TPR and pain levels, treat any pain or anxiety present, provide TGH analgesics and supportive meds.	Continue analgesic CRI until less painful, bolus opioids, NSAIDs (if not given already), and gabapentin.

Table 1. The 4 phases and their goals, specific actions, and example drugs used to achieve both.

*Note: the authors and contributors prefer postoperative NSAID administration despite literature showing superior intraoperative analgesia. This is because arterial hypotension is such a prevalent complication under general anesthesia. NSAIDs can alter kidney perfusion and increase the risk of postoperative AKI's if hypotension persists.

Before delving into each phase of anesthesia, an anesthetist must understand the Anesthesia Care Continuum. Although simplified into phases for practicality of education, an anesthesia/analgesia plan spans well beyond the scope of the operating room. Whether as premedication with gabapentin/trazodone and/or maropitant or simply thoughtful communication to prepare the clients, families must start preparing for their pet's anesthesia prior to the patient arriving at the hospital. The A/A plan does not end until the recheck appointment after surgery and may not end there in some chronic management cases. This is important to conceptualize as the anesthetist is truly responsible for the "whole picture."

Firstly, the preanesthetic phase is defined as all happenings prior to induction of anesthesia. A preoperative assessment of the anesthetic patient

is crucial to minimize risk and complications. With absolutely no exceptions, every anesthetic candidate must receive a thorough physical examination (PE) or at least a temperature, pulse, and respiration measurement (TPR). In "gold-standard medicine," every patient should receive preoperative lab work, typically including a complete blood count (CBC), a biochemistry panel focused on hepatic and renal function, and a urinalysis. Any abnormalities may increase risk of complications. A common abnormality seen in geriatric patients is impaired renal or hepatic function. This can affect the way the body metabolizes and eliminates drugs. Besides lab work, the clinician must use their judgment to decide whether further diagnostics are indicated. Kidney, liver, and heart and lung function are the most crucial parameters to check prior to anesthesia. Imaging evaluation of the thoracic and abdominal cavities may be indicated in older or compromised animals. Other advanced diagnostic techniques include echocardiogram and CT scans that may be indicated in specific cases.

The American Society of Anesthesiologists (ASA) has set forth a system to quickly assess patient risk. This is known as the ASA Physical Classification Status.[3] Each classification relates to a varying level of comorbidities that increase risk of anesthetic complication and death **[Table 2]**, starting at ASA I, a patient with no risk, going up to ASA V, a patient who will die without the surgery. In most general practice settings, an anesthetist will commonly be working with ASA 1, 2, and 3, rarely ASA 4, and almost never ASA 5. In general, ASA 4 and 5 patients should be referred to a Board Certified Veterinary Anesthesiologist. These cases can be quite complicated and require more skill and resources most general practices are able to accommodate.

ASA Status	Definition	Examples
ASA I	A healthy patient, no systemic disease	Laceration, Grade I dental disease, hip dysplasia
ASA II	A patient with mild systemic disease, neonates and geriatric patients[3] (>7 y/o)	Mild/compensated heart disease (stage B1 degenerative mitral valve disease), local and benign masses
ASA III	A patient with severe systemic disease	Mild acute issues (vomiting, anorexia), moderate heart disease (stage B2 degenerative mitral valve disease)
ASA IV	A patient with severe systemic disease that is a constant threat to life[3]	Shock, sepsis, uncontrolled diabetes mellitus
ASA V	A moribund patient who is not expected to survive without the operation	Profound shock, major trauma, ischemic bowel obstruction

Table 2. ASA statuses, their definitions, and examples.[3]

Once an assessment is complete, the anesthetist must deliver an appropriate cocktail of medications called the "premedication" or "premed". There are 3 main goals of premedication including relieving

anxiety, tranquilization, and analgesia. Anxiety is present in almost every patient seen in the perioperative setting. Every patient (no exceptions) must receive an anxiolytic (a medication that relieves anxiety). Some potent anxiolytics include alpha-2 agonists (e.g., dexmedetomidine), phenothiazines (i.e. acepromazine), butorphanol, occasionally benzodiazepines (e.g., midazolam), and oral anxiolytics (gabapentin/ trazodone). Even if a patient does not seem anxious, the anesthetist must assume the presence of anxiety. Feline patients are incredibly more predisposed to perioperative anxiety. The use of Pre-Visit Pharmaceuticals (PVP's-- most commonly gabapentin +/- trazodone) is especially advantageous in feline patients to prevent anxious wind-up when entering the hospital. Anxiety can cause an unpredictable anesthesia and lead to poor recovery quality. It is also important to note that anxiety and pain are synergistic. Pain can cause anxiety, and anxiety can make pain worse. Again, it is crucial to treat both pain and anxiety in all hospitalized patients.

One of the most important ideas for the preoperative phase is the fact that a patient may emerge from anesthesia in the same state they were induced. For example, a patient that is induced while vocalizing may wake up vocalizing. An anxious or aggressive patient may wake up anxious or aggressive. There is a common misconception of the need to induce general anesthesia quickly when an animal is uncooperative or severely anxious. However, a focus on heavy and adequate anxiolysis and tranquilization delivered in the preoperative phase will aid to eliminate perioperative stressors, reducing potential complications. Not covered in this book, there are several stages and planes of anesthesia. Loosely, it is important to transition a patient from sedated to unconscious smoothly. If one administers an anesthetic too quickly, this may cause panic and dysphoria during induction and therefore cause a poor recovery. A gentle transition from a light phase of anesthesia to a deeper one during induction is advantageous to avoid dysphoria upon emergence.

Premedication is also important for tranquilization. Tranquilization is a subset of sedation but is typically less relaxing than sedation. Sedation can produce varying levels of sleep and hypnosis, while tranquilization relaxes and calms the patient to a lesser degree. Another distinguishing feature is that sedated patients can normally tolerate noxious stimulation while tranquilized patients will typically break through their tranquilization and react to noxious stimulus. These words may be used interchangeably, but it is important to understand the goal of premedication is not typically full sedation. There are some cases in which heavy sedation may be required. The anesthetist must use their best judgment to determine the

degree of sedation required for their patient. An appropriate and harmonious balance should be found between a fully conscious patient and a recumbent patient.

The third important aspect of premedication is analgesia and MAC-sparing effects. Selecting the most appropriate analgesic can be difficult as the patient is not yet feeling pain (in an elective procedure). This creates an interesting barrier, as the anesthetist must predict the level of intraoperative and postoperative pain the patient will experience. Analgesia also expresses a MAC-sparing effect. MAC (minimum alveolar concentration) is defined as the minimum alveolar concentration of an inhalant anesthetic required to keep 50% of the patient population immobilized when a noxious stimulus is delivered. In practice, this loosely translates to the percent of inhalant anesthetic required to keep a patient unconscious while experiencing pain; therefore, MAC-sparing describes a technique in which analgesics and sedatives are administered pre- and intra-operatively to reduce the amount of inhalant required to keep a patient unconscious during surgery. MAC-sparing techniques typically also decrease injectable anesthetic requirements. Analgesics provide MAC-sparing effects via the decrease in pain the patient is experiencing. Tranquilizers can also be used as a MAC-sparing agent, aiding in hypnosis and relaxation. The amount of MAC that is spared by each agent is species and dose (for most drugs) dependent.

Generally, every patient should be allowed to rest quietly for 10-30 minutes after premedication administration. However, patients may become hypothermic if they become very sedate and do not move. Monitor temperature and provide heat support if allowed to rest for more than 10 minutes. Provide soft bedding and a small cage or kennel to minimize risk of injury if the patient stumbles or falls during this period where they are entering a state of altered consciousness.

Premedication cocktails must be chosen based on anesthetic risk, level of anticipated perioperative pain, and mentation or behavior of the patient. Premedications are best administered using a multimodal approach (i.e., cocktail). Effective combinations typically include an opioid and a sedative or tranquilizer. Common premedicant opioids in general practice include methadone, hydromorphone, and buprenorphine. Morphine is becoming a lesser used opioid due to its higher side effect profile; better analgesia may be achieved with safer drugs. Butorphanol is avoided due to weak analgesia and mu-opioid receptor antagonism. Buprenorphine provides minimal sedation; however, it also has the fewest opioid-related side effects (low risk of vomiting, diarrhea, constipation, dysphoria, vocalization, respiratory depression, etc.). Buprenorphine provides less

analgesia than methadone and hydromorphone. Methadone and hydromorphone are the preferred full-mu agonists for premedication and provide good sedation. Fentanyl is generally reserved for higher-risk or very painful patients and generally given IV due to its titratable effects and large volume. Once the proper opioid is selected, a sedative should be added to enhance opioid analgesia and sedation. When certain sedatives (acepromazine, dexmedetomidine, midazolam) are used with opioids, it induces a state of neuroleptanalgesia, which is described as a deeper state of analgesia with balanced sedation. Classically, this can be achieved with an opioid and a phenothiazine tranquilizer (i.e. acepromazine).

The preoperative phase is also an ideal time for administration of other supportive medications. Typically, these can include antiemetics, anti-nauseas, antibiotics, prokinetics, and sometimes NSAIDs. Some practitioners recommend NSAIDs to be held until the postoperative phase because of potential renal vasoconstriction, as they can increase the risk of renal ischemia from anesthetic hypotension. If not contraindicated, every patient should receive an NSAID, whether pre- or postoperatively. Another class of medications typically implemented in the preanesthetic phase are antibiotics. Prophylactic antibiotics are widely used in practice to prevent surgical site infection (SSI); although still a common practice today, newer studies are suggesting not using antimicrobial prophylaxis routinely.[4] Instead, new findings suggest no need for antimicrobial prophylaxis for short (<1 hour), elective procedures (e.g., spay/neuter).[4] In cases of large anatomical involvement, lacerations, dental procedures, and high-risk contamination procedures, antimicrobial prophylaxis is recommended. The antibiotic chosen is typically associated with the most likely pathogen to infect the site and the antibiotic's ability to penetrate the tissue involved in the site. The most common antibiotics used in surgery are penicillin-G, ampicillin, cefazolin, and clindamycin. Antibiotics can be repeated or given at a different phase; it is all dependent on the procedure and its associated-potential SSIs. Indications for repeat administration include surgery time that extends the elimination half-life of the drug, heavy contamination, and volume loss. The anesthetist is typically not responsible for antibiotic selection; the surgeon will order the antibiotic of choice with appropriate dosing frequencies.

In practice today, anticholinergic agents are not routinely given prophylactically, as this would put unnecessary strain on the heart.[5] These drugs are now commonly used to treat (not prevent) clinically significant or intolerable bradycardia. Other indications include drying secretions, organophosphate poisoning, and blunting the hemodynamic

parasympathetic response. These agents include atropine and glycopyrrolate that both decrease parasympathetic activity in the SA and AV nodes in the heart (i.e., increase heart rate). They are commonly referred to as "anticholinergics" as the parasympathetic nervous system is widely mediated by the neurotransmitter, acetylcholine. Anticholinergics today are best given when clinically significant bradycardia is present. Notably, tolerable bradycardia can include slight variations of normal to large decreases in resting rate. One example of this is alpha-2 agonist-induced reflex bradycardia; some reports claim large dog heart rates in the 30s while still maintaining adequate blood pressure and perfusion due to significant peripheral vasoconstriction.[6] In this example, one should wait until the blood pressure begins to drop until administering an anticholinergic agent.[6] A tolerable heart rate is indicated by stable perfusion (i.e., adequate blood pressure, mucous membrane color, capillary refill time, and pulse quality). If the blood pressure begins to drop, it would indicate an intolerable heart rate because the heart is no longer compensating for vasoconstriction. In that case, the heart is not responding to a decrease in vascular tone and requires an anti-bradycardic agent (i.e., atropine/glycopyrrolate) to improve cardiac output and subsequently blood pressure. In some cases, it is best to reverse alpha-2 agonists in cases of significant and potentially fatal bradycardia instead of administering an anticholinergic to bring the heart rate up. However, atipamezole (dexmedetomidine reversal agent) may lead to hypotension and no increase in cardiac output in anesthetized cats that received dexmedetomidine.[27] Anticholinergics are a second or third line treatment in dexmedetomidine induced bradycardia. Myocardial ischemia may result if the heart is made to beat faster against increased resistance, leading to increased myocardial oxygen consumption. IV lidocaine 2% at 2 mg/kg may also transiently improve bradycardia in dogs[28]; this exact mechanism is not well known but it has been shown to increase heart rate for 10-15 minutes. A CRI of lidocaine may provide a steady plane of improved heart rate and hemodynamic parameters.[28] Although, one must weigh the risks and benefits of IV lidocaine administration. In essence, there is no need to treat bradycardia unless there is evidence of poor hemodynamic status (e.g. low blood pressure or signs of poor perfusion) to avoid undue strain on the heart.

Antihistamines are occasionally given during the preoperative phase. The most common antihistamine used in practice is diphenhydramine (Benadryl). Antihistamines may be indicated for confirmed or suspected mast-cell tumor removal, allergic reactions to medications (most commonly

morphine), and as an adjunct for sedation. Simply put, histamines cause vasodilation and subsequent hypotension. Histamines are released from mast-cells. Histamine-mediated or mast cell-mediated reactions can therefore increase risk of hypotension and related complications. Removal of the mast cell tumor may cause rapid and large quantities of histamine release.

In most cases, antiemetics are highly encouraged. Antiemetics (e.g. maropitant) prevent/treat vomiting and also typically have *no* effect on nausea. This complies with patient safety and decreases risk of subsequent aspiration perioperatively. Anti-nausea medications treat central nausea which may or may not inhibit vomiting. Anti-nausea medications fit more with patient comfort but still improve patient safety. Importantly, these two medication classes are separate and deserve clear distinction from one another. Anti-nausea medications can exhibit an antiemetic effect *if* the vomiting is mediated by nausea. A common anti-nausea used in practice is ondansetron.[7] Metoclopramide is thought to act as both an antiemetic and an anti-nausea agent. If given IV, antiemetics/anti-nauseas must be given 5 minutes prior to premedication, up to 30-45 min if given IM/SC, and at least 90 min if given PO. Notably, brachycephalic patients have an increased risk of gastroesophageal regurgitation due to the prevalence of hiatal hernias and low intrathoracic pressure during inspiration. It is recommended to give gastroprotectant agents, including antiemetics, anti-nausea agents, and prokinetics to these patients. Silent regurgitation may occur such that once the patients become sedate after premedication, the risk of aspiration as well as upper airway obstruction is heightened in brachycephalic breeds.

Induction

The goal of induction is to provide a smooth transition from a state of lessened consciousness (sedation) to a state of complete unconsciousness (general anesthesia) with minimal changes to normal physiologic function. The *perfect* induction drug provides analgesia as well; however, this does not exist. This furthers the need for multimodal practices during the induction phase. Induction drugs are typically given IV, but specific cocktails that produce unconsciousness can be given IM if desired. As stated previously, “a patient will wake up how they went down.” Aside from adequate premedication, it's important for the anesthetist to induce patients in a calm and organized manner. Most patients given a general anesthetic will require a definitive airway (i.e. endotracheal tube). Patients who are not intubated but are considered to be under general anesthesia

should always be provided with flow-by or mask oxygen. An example of this patient would be a feline neuter. Most practitioners give 1 simple injection of "kitty magic" (commonly dexmedetomidine, ketamine, and butorphanol). The patient is then rendered unconscious, but they can typically still protect against aspiration and sometimes maintain a patent airway. However, intubation is still the most effective way in maintaining a patent airway.

It is important to note that cats can maintain their airway without assistance at much deeper levels of anesthesia than a dog. If not routine, a cat should always be intubated (gold standard would be intubating any procedure including spays/neuters). However, feline intubation comes with an increased risk compared to that of dogs. Cat's have very thin and frail trachea that are prone to tears and injury during an intubated event. Inflating the cuff of an ETT with more than 6mL of air in a cat can significantly increase risk of tracheal tear.[24] To form an adequate seal, only 1.6 +/- 0.7mL is required.[24] If more than 2.3mL is required to form a seal, the ETT is likely too small for the patient. Another important intubation note for feline patients is their response to laryngeal stimulation: cats can spasm and close their vocal cords (the entry to the trachea) in a process called laryngospasm. This can be prevented by topical administration of 0.10 mL lidocaine 2% and/or administration of additional induction agents (especially propofol) to deepen the patient's anesthetic plane and blunt the sympathetic response from intubation.

Generally, almost all patients (both cat and dog) that are induced under general anesthesia should be intubated. Any patient that has lost their swallow reflex should be intubated. Specific indications of intubation include general anesthesia (exceptions listed above), oral/dental procedure, fine control of anesthetic depth, and all patients ASA II or above. Oral-endotracheal intubation is the most common method of endotracheal intubation in which the ETT is passed through the mouth and into the trachea. Oral-endotracheal intubation is almost always the method of use in general practice. Insertion of an ETT should only be done by an experienced anesthetist and must be done immediately once the patient is unconscious.

Preoxygenation is a technique in which the patient receives flow-by oxygen for 3-5 minutes prior to the administration of induction medications. This decreases the risk of hypoxemia brought on by post-induction apnea.[8] All patients subject to induction of general anesthesia, ideally, should be intubated. Some inequality sedated patients do not tolerate preoxygenation. If this is the case, additional sedation or very low

dose induction agents may be used to facilitate preoxygenation. Unless the patient has an emergent airway crisis, the anesthetist should provide oxygen for 3-5 minutes before induction. This technique is not required in other patients but may be advantageous to prevent hypoxemia. For the most part, preoxygenation is not contraindicated in most cases and therefore does not cause harm if the anesthetist implements this technique for all patients.

Induction is one of the most unpredictable phases of anesthesia. Induction drugs commonly cause rapid changes in hemodynamics and ventilatory function. It is important to monitor the patient adequately during induction. Some general practices today still lack proper monitoring in the surgery prep area where induction is generally performed. It is recommended to monitor ECG, SpO_2 and blood pressure during induction.

A common adverse reaction of induction is hypoventilation or respiratory depression.[8] Most of the common veterinary induction drugs (e.g. propofol, alfaxalone) exert some effects on the ventilatory region of the brain. Therefore, respiratory depression or apnea is a dose-dependent and administration rate-dependent side effect of propofol and alfaxalone specifically. Ventilatory depression may not always result in hypoxemia depending on the degree of depression, the patient's oxygen reserve, and perfusion status. Mechanical ventilation may be required for patients that cannot tolerate the transient hypoventilation. Another common ventilatory phenomenon of anesthetic induction is apnea or the cessation of breathing due to most agents slowing activity in the brain stem . It is crucial the anesthetist recognizes this early. This can happen as the induction drugs are being administered or immediately after. If this is recognized, discontinue administration of respiratory depressing agents (i.e., propofol or benzodiazepines). If recognized, stop administration of respiratory depressant and provide manual ventilation if oxygen saturation drops below 94%. If unrecognized, apnea is generally self-limiting and/or transient, but mechanical ventilation is indicated if persistent or hypoxemic.

Maintenance

Once the patient is safely induced under general anesthesia and has the appropriate airway in place, the anesthetist's job is to keep the patient unconscious and stable. One of the most crucial aspects in maintaining safe anesthesia is a balanced, multimodal approach to maintenance anesthesia. Inhalant anesthetics cause systemic vasodilation and renal vasoconstriction (isoflurane specifically). They can also raise ICP and depress myocardial function. This means that high levels of inhaled anesthetics increase the risk of anesthetic complications. A technique to prevent this is by using a

balanced maintenance method with MAC-sparing agents (i.e., intraoperative analgesics and sedatives). In some cases where high levels of inhalants can be detrimental (hemodynamically unstable patients), partial intravenous anesthesia (PIVA) may be required. PIVA's can include benzodiazepines (midazolam), ketamine, an opioid, and/or dexmedetomidine. Total intravenous anesthesia (TIVA) is usually more uncommon in small animal general practice but can be implemented for unstable patients or those who cannot tolerate any level of inhalant anesthetic. Generally, TIVA's consist of propofol and rarely alfaxalone.

Recovery

Recovery is a critical and often underestimated phase of the anesthetic continuum. It represents the transition from a pharmacologically induced unconscious state back to physiological normalcy and consciousness. The recovery period is not simply the cessation of anesthetic drugs but rather a dynamic phase involving neurological, cardiovascular, respiratory, thermoregulatory, and analgesic stabilization. High-quality recovery care is essential for minimizing morbidity, ensuring patient comfort, and identifying complications early.

From a physiological standpoint, anesthetic agents—particularly inhalants and sedatives—exert residual effects on respiratory drive, thermoregulation, gastrointestinal motility, and cardiovascular tone. As these agents are metabolized or redistributed, the animal's vital functions begin to normalize; however, the transition is rarely uniform or without clinical consideration. Thus, active and intentional monitoring during the recovery phase is as critical as intraoperative anesthetic management.

Postoperative analgesia is the cornerstone of a smooth recovery. Because many anesthetic agents provide minimal to no residual analgesia, supplemental pain control should be administered prior to emergence to preempt nociception and avoid wind-up phenomena. Protocols should be tailored to the patient's procedure, pain score, comorbidities, and response to intraoperative analgesia. Common strategies include opioid redosing, nonsteroidal anti-inflammatory drugs (NSAIDs), dexmedetomidine microdosing, gabapentinoids, and the continued use of local anesthetic techniques such as soaker catheters or epidurals. In moderate to severe pain cases, opioid CRIs (e.g., fentanyl, hydromorphone) or ketamine infusions may be continued into the recovery period for sustained analgesic coverage and central desensitization.

Pain assessment should begin before extubation and continue at regular intervals during recovery. Validated pain scoring systems, such as

the Glasgow Composite Measure Pain Scale or the Colorado State University Pain Scales, should be applied consistently. Sedation, dysphoria, and emergence delirium must be differentiated from pain to avoid misinterpretation; this often requires close attention to body language, vocalization, heart rate trends, and response to gentle palpation or interaction. When in doubt, analgesic trials may be used diagnostically—administering a low-dose opioid or adjunctive analgesic and observing for clinical improvement.

In addition to analgesia, other parameters should be vigilantly monitored. Body temperature should be assessed frequently, as hypothermia is common in the early postoperative period and is associated with prolonged drug metabolism, delayed recovery, shivering, and increased oxygen consumption. Active warming techniques, such as forced-air warmers or warm water blankets, should be used in conjunction with temperature monitoring to avoid iatrogenic hyperthermia.

Cardiovascular function must also be closely evaluated. Bradycardia or tachycardia may reflect residual drug effects, hypovolemia, pain, or dysrhythmias. Blood pressure should be monitored until normotension is confirmed, especially in patients who received vasodilatory agents, alpha-2 agonists, or epidural anesthesia. Oxygen saturation and respiratory rate should be tracked until the patient is breathing spontaneously with normal pattern and effort, and oxygen supplementation should be continued until arterial oxygenation is consistently adequate.

Before extubation, patients should demonstrate adequate swallow reflexes, strong jaw tone, and the ability to maintain a patent airway without assistance. In brachycephalic or high-risk patients, extubation should be delayed until the patient is fully awake and can protect their airway, often requiring extended monitoring or re-sedation in cases of distress.

Once extubated, patients should be positioned in sternal recumbency, in a quiet, padded, temperature-controlled environment. Recovery should be supervised until the patient is consistently maintaining a normal respiratory pattern, normothermia, spontaneous movement, and responsiveness to stimuli without distress or disorientation. The presence of dysphoria, particularly in patients recovering from opioids or ketamine, should be differentiated from pain and addressed appropriately. Low-dose sedatives such as acepromazine or dexmedetomidine may be used judiciously to ease emergence agitation.

Before discharge from the hospital, several parameters must be assessed and documented. These include the patient's ability to ambulate,

urinate voluntarily, and maintain normothermia without active warming. Pain should be well-controlled, with clear instructions for at-home analgesia and a schedule for reassessment. Discharge medications should be reviewed with the owner, including expected side effects, dosing instructions, and when to seek veterinary attention. Surgical sites must be clean, dry, and appropriately protected (e.g., via e-collars or bandages), and any drains or sutures should be explained to the caregiver.

Communication with the client during this phase is essential to reinforce the importance of continued pain management, restricted activity, and monitoring for complications such as anorexia, vomiting, or changes in behavior that could indicate discomfort or infection. Written discharge instructions should accompany verbal counseling to ensure owner compliance and patient safety.

In conclusion, recovery from anesthesia is a complex, dynamic period that requires active intervention, multimodal analgesia, and diligent monitoring. It represents both a clinical responsibility and an opportunity to safeguard patient welfare, prevent complications, and ensure a return to normalcy with comfort and safety. High-quality recovery is not incidental —it is deliberate, evidence-based, and essential to successful anesthetic outcomes.

Surgical/Acute Analgesia

There are several categories of analgesics, and each acts at a specific point of the pain pathway. First, one must understand the physiology of pain. Pain is first received as a chemical or mechanical insult to the peripheral nerves where that signal is turned into a chemical signal. This process is called transduction. Next, the peripheral nerves carry the signal to the spinal cord, known as transmission. Once in the spinal cord, the impulse travels through the dorsal horn of the spinal cord in a process called modulation. Here, inhibitory neurons can blunt and decrease a pain signal to the spinothalamic tract. Drugs that affect modulation exert their action at this point. Finally, the pain signal is processed in the thalamus and cortex, which is called perception. Effective analgesia targets each of the described processes **[Table 2]**. If not contraindicated, every patient should receive a drug that treats each point of the pathway to effectively manage pain in a multimodal fashion.[9]

Pain Pathway	Effective Drugs for Pathway
1. Transduction	NSAIDs, Opioids, Local Anesthetics[9], Corticosteroids
2. Transmission	Alpha-2 Agonists, NSAIDs, Opioids, Local Anesthetics, NMDA-antagonist, Gabapentinoids[9], NK-1 antagonist
3. Modulation	GABA-ergic/-agonist, NMDA-receptor antagonist, Opioids, Local Anesthetics, Alpha-2 Agonists[9], NK-1 antagonist
4. Perception	General Anesthetics, Alpha-2 Agonists, GABA-ergic/-agonist, Opioids, NMDA-receptor antagonist, NSAIDs[9], NK-1 antagonist

Table 2. Pain pathway and analgesic action location. Note: Butorphanol is not considered an adequate opioid analgesic for most painful patients.

As explained previously, analgesia is a large part of an anesthesia plan. There are several analgesic drug classes with which the anesthetist must be familiar **[Table 3]**. Multimodal analgesia is the practice of using several analgesics at lower doses than normal to achieve the same pain-free effect while minimizing adverse effects from one particular drug. Ideally, a true multimodal analgesia plan includes one drug from each analgesic class (if not contraindicated). It's also important to understand that stress can make pain worse and vice versa. Cortisol may actually sensitise nociceptors making acute pain in high FAS patients.

Most analgesics work by inhibiting neuronal excitation and therefore slowing neuronal transmission.

As made clear by now, anesthesia and analgesia go hand-in-hand. However, this is not necessary just a theory but also physiologic fact. Generally, most analgesics exert their action in both the brain and spinal cord. The brain is where sedation, hypnosis, and general anesthesia is initiated by inhibitory drugs (i.e. anesthetics and analgesics). The spinal cord, however, is where analgesia is mediated by inhibitory drugs. The brain and spinal cord parenchyma have the same receptors and utilize mostly identical pathways in neurotransmission. Therefore, a given analgesic has the innate potential to cause CNS effects (i.e. sedation). For example, ketamine, a potent NMDA-receptor antagonist, works in the thalamus to block afferent sensory signals coming from the spinal cord, therefore, causing dissociation of the cortex and the thalamus. However, in the spinal cord, ketamine's effects lead to decreased transmission of afferent signals in the dorsal horn. Ketamine's main effects (i.e. analgesia and dissociation) are mediated by the NMDA-receptor. Importantly, it is the *location* of those receptors, not the physiology, that differs and yields different clinical effects. Here, we will discuss the various classes and drugs

used to inhibit pain signals at the spinal and supraspinal levels.

Opioids

Opioids have long been the cornerstone of both human and veterinary analgesia. This is because of the simple fact that they work extremely well and reliably. However, they bring with them a lot of side effects. Modern analgesic techniques suggest to minimize opioid use as much as possible to improve postoperative appetite and subsequent recovery. It is still important to use opioids judicially in painful patients where alternative therapies may be contraindicated. Opioids are a class of compounds that bind to opioid receptors in the peripheral and central nervous systems. There are several classes of opioid receptors; the mu-opioid receptor, mediates most of the clinical effects such as analgesia, sedation, and adverse effects; the kappa-opioid receptor, mediates visceral analgesia and mood effects; the delta-opioid receptor, mediates little of the clinical effects but contributes to visceral analgesia and sedation. There is also the nociceptin receptor which most opioid compounds have activity at but literature suggests the other three receptors mediate the significant majority of effects. All opioids agonize or antagonize to varying degrees each subtype in a different ratio, known as biased agonism or functional selectivity. No matter the subtype of opioid receptor, when agonized, they cause inhibition of a neuron. All opioid receptors are G protein coupled-receptors (GPCR) which have two downstream signaling pathways; the β-arrestin pathway and the G protein pathway. The G protein pathway is the cascade responsible for analgesia and sedation while the β-arrestin pathway produces most of the adverse effects such as respiratory depression and constipation. When the G protein pathway is activated it inhibits adenylyl cyclase which prevents cAMP from being formed. This causes K^+ channels to open causing hyperpolarization and Ca^{2+} to close resulting in decreased neurotransmitter release. Ultimately, this causes pain relief by slowing or completely inhibiting pain signals in the dorsal horn of the spinal cord. Opioids specifically exert their primary analgesic action at the second order neuron synapse in the substantia gelatinosa of the dorsal horn. This is where the primary nociception was initiated and is being transmitted to the spinal cord. The opioid receptor is located presynaptically to inhibit downstream effects as described previously. Opioids also work in the brain to alter perception of pain and cause sedation, respiratory depression, and vomiting. The respiratory depression is caused by inhibition of signaling in the medulla oblongata which is responsible for respiration. The vomiting is mediated by mu-opioid

receptor activation in the chemoreceptor trigger zone (CRTZ) which are generally located on GABAergic neurons. When the GABAergic neuron is inhibited, it slows the release of GABA, the primary inhibitory neurotransmitter. In this location of the brain, GABAergic neurons synapse to dopaminergic neurons; because of the inhibition of the GABAergic neuron, the dopaminergic neuron is disinhibited (or excited) which directly causes nausea and vomiting (specially via the D2-receptor).

The clinical use of opioids is ever changing and very provider-dependent. Generally, any patient experiencing significant pain should receive an opioid if other modalities are not employed (i.e. locoregional techniques, non-opioid analgesic, and nonpharmacologic techniques). If the pain would make a person wince, limp, or avoid moving, it's likely enough to justify opioid use in a dog or cat. In general practice, opioids are best utilized as a preemptive measure in an anesthetic protocol. Literature shows that when pain is treated before it occurs, the patient is less painful after the noxious event. For example, all spays and neuters should routinely receive an opioid preoperatively. Opioids also provide sedation which makes them a reliable choice for a premedicant. Opioid receptors are co-located with alpha-2 receptors and work synergistically down-stream with D-2 receptors. Therefore, opioids are best used for premedication with an alpha-2 agonist or acepromazine. Specifically, common premedicant opioids are hydromorphone, methadone, butorphanol, and buprenorphine. Importantly, butorphanol should never be used as the primary analgesic for an anesthetic protocol; butorphanol is a mu-antagonist and provides very poor clinical analgesia as it only agonizes delta and kappa. Local blocks, NSAIDs, and ketamine/dexmedetomidine CRI's are recommended if using butorphanol as the opioid of choice. Opioids, however, produce a lot of side effects especially when the patient is not experiencing pain. Common side effects include nausea, vomiting, panting, hyperthermia, vocalizing, drooling, sedation, constipation or diarrhea, respiratory depression, ileus, bradycardia, and gastroesophageal sphincter relaxation. Patients that experience pain prior to receiving an opioid (e.g. long-bone fracture) generally experience less severe side effects. Buprenorphine provides another caveat to premedication; most studies show it provides poor MAC-sparing effects and this translates clinically. This is because buprenorphine is a partial mu-agonist opioid; buprenorphine only agonizes the mu receptor to a lesser extent than other opioids which allows for very unique applications.

Buprenorphine is currently the only FDA-approved opioid for use in veterinary medicine for analgesia under the brand name Simbadol and

Zorbium (butorphanol is also FDA-approved but again, does not provide adequate analgesia). Notably, there are no approved long-acting buprenorphine products for dogs. Buprenoprhine displays interesting pharmacokinetic characteristics. Because of its partial agonist properties, it binds to the mu-opioid receptor very strongly but only partially. This characteristic is responsible for both a long onset and long duration of effects. Partial agonism is also responsible for buprenorphine's unique low-incidence of opioid side effects (minimal sedation and minimal GI effects). Up until recent years, it was thought that buprenorphine did not provide equipotent analgesia to full-mu agonists like hydromorphone due to the ceiling effect. This effect being that the dose of buprenorphine is not a linear relationship with its effect, in fact, it was thought to plateau at a certain dose. However, recent studies suggest that higher doses of buprenorphine may yield stronger analgesia that is equipotent to a full agonist. Generally, an average 6 hour dose of buprenorphine is 0.02 mg/kg IV (equal bioavailability for IM administration is generally 0.025 mg/kg). However, higher doses, such as 0.05 mg/kg IV have been reported to produce equipotent analgesia to a full mu agonist. Even with this evidence, we still know buprenorphine does produce some kind of ceiling effect. The labeled dose of Simbadol is 0.24 mg/kg SC for cats (12 times greater than the standard IV dose) and lasts 24 hours. This is generally thought to be because the plasma levels of buprenorphine become so high that they slowly decrease over 24 hours and maintain enough plasma levels to provide analgesia the entire time, until eventually they fall below a given concentration that does not provide analgesia (usually regarded as <0.5ng/mL of buprenorphine in cats). Simbadol has been experimentally shown to provide similar pharmacokinetics in dogs given 0.12 mg/kg SC but the dogs in this study were very euphoric (not dysphoric) and displayed lethargy and hyporexia. Anecdotally, the author of this book prefers 0.08 mg/kg SC as less nausea and hyporexia are seen. Zorbium is another long acting buprenorphine product for use in cats only. Similar to Simbadol, it contains no polymer delivery system but uses pharmacokinetics to achieve a long duration of 4 days. Zorbium is applied transdermally and is absorbed into the stratum corneum and deeper layers of the epidermis. Intercellular matrices are almost like a morder that will trap the buprenorphine solution and slowly release it. Zorbium displays “flip-flop” pharmacokinetics which describes that its absorption occurs at a slower rate than it is excreted; this is counteracted by the large dose that’s usually given (8-20mg). Cats tolerate these long acting products relatively well. The most common adverse effects include hyperthermia, mydriasis, and euphoria (not

dysphoria) which can present as hyperlocomotion. These effects are mild and self-limiting in most cats and generally resolve after 24 hours (in both Simbadol and Zorbium). Anecdotally, the author of this book finds most owners report tolerable side effects.

The next group of opioids for discussion are full-mu agonist opioids. These classically include morphine, hydromorphone, fentanyl, and in recent decades, methadone. Full-mu agonist compounds bind to the mu opioid receptor to the fullest extent. They occupy a dose-dependent percentage of opioid receptors which makes titration of effects straight forward. Essentially, the more of a full-mu is given, the more profound effects are seen, including both desired and undesired effects. Full-mu agonists are preferred over buprenorphine for premedication as they provide more MAC-sparing effects. Fentanyl is an extremely potent opioid but is not commonly used in general practice due to its dilute concentration and short duration of action (although it is quite inexpensive). Its preferred use is in speciality and referral settings for high-risk anesthesia as it is easily reversible and titratable. The current two most popular full-mu agonist opioids in general practice are hydromorphone and methadone (sometimes morphine but becoming much less common). Hydromorphone is a potent, synthetic opioid that works rapidly and very well to produce deep sedation and profound analgesia. When combined with dexmedetomidine or acepromazine, hydromorphone's effects are amplified as described previously. Hydromorphone is very pro-emetic due to strong downstream D2-agonism. This can cause profound nausea and vomiting which can be quite uncomfortable for patients, especially postoperatively. It also generally causes both dogs and cats to quickly become hyperthermic. That being said, hydromorphone is a versatile opioid that can be used preanesthetic for sedation, intraoperative for partial intravenous maintenance, and for easily titratable analgesia. Hydromorphone is also the cheapest opioid currently available on the US drug market. However, all of this makes hydromorphone quite appealing to both human and veterinary facilities which means the drug is in short supply occasionally. Hydromorphone shortages have slowly pushed buyers towards methadone, a semi-synthetic opioid with NMDA antagonist effects. Methadone is becoming quite popular in general practice and referral/specialty care settings. Methadone is often considered the "Goldilocks Opioid". When given IV, methadone 0.2 mg/kg provides profound analgesia within 1 minute after administration that persists for up to 6 hours (long durations have been reported with higher doses). This dose of methadone generally causes minimal nausea and vomiting but still does induce panting and

hypothermia. In large dogs, methadone is generally not sedating and higher dose sedatives must be administered in conjunction to achieve adequate sedation for preanesthesia. However, in small dogs and cats, methadone is very sedating and when combined with an alpha-2 agonist, benzodiazepine, or acepromazine, produces reliable sedation.

There are several oral opioid formulations commonly used in human medicine. However, oral administration of these agents has proven to not be efficacious due to a high first-pass rate. Tramadal has historically been preferred for TGH analgesia. However, recent literature suggests its analgesia is non-existent in acute pain in dogs. Tramadol itself is not an opioid, it's a pro-drug that is metabolized into an active metabolite that agonizes the mu opioid receptor (MOR). However, this metabolization occurs at a very low rate in dogs but a clinically significant rate in cats. Because of this, tramadol, a commonly used oral opioid, provides minimal analgesia when used in dogs for acute pain. Tramadol does provide true opioid analgesia even when used alone in cats; however, tramadol is known to taste bitter and discourages its oral use in cats. Most of tramadol's analgesia is serotonin mediated which may be more clinically applicable in cases of chronic pain.

Finally, we must address how to treat opioid related side effects. As noted previously, full-mu agonist opioids cause a wide variety of effects. The most common and concerning include vomiting, hypersalivation, bradycardia, hyperthermia, and inappetence. To prevent vomiting secondary to opioids, premedication with an antiemetic is crucial. These antiemetics include maropitant, metoclopramide, or acepromazine (generally maropitant is the first-line prophylactic drug). Metoclopramide and acepromazine block the D2 receptor therefore inhibiting opioid induced vomiting. Ondansetron may help decrease opioid induced nausea but it generally does not stop the vomiting due to dopaminergic pathways not being inhibited by ondansetron's serotonergic modulation. Hypersalivation is also commonly seen with opioids and may be treated with ondansetron, but generally anticholinergics are more effective. Glycopyrrolate 5 mcg/kg IV is anecdotally preferred by the author of this book to suppress opioid induced hypersalivation. Glycopyrrolate can also be used to treat opioid induced bradycardia which is mediated by the vagus nerve and increased vagal tone. Opioid induced hyperthermia is best managed with proper hydration and a cool environment but an NSAID can also be administered in an attempt to normalize body temperature. Finally, inappetence can be seen for hours to days after a pet receives an opioid. Some dogs and cats are very sensitive to the dopaminergic effects of

opioids. Most of these effects can be resolved with oral or parenteral metoclopramide. Other therapies include capromorelin or mirtazapine (less preferred due to moderate serotonergic interactions with opioids).

Reversal of full mu-agonist opioids may be performed with naloxone or butorphanol. Reversal may be indicated in cases of severe cardiopulmonary depression, severe dysphoria, or cardiac arrest. Butorphanol is the preferred agent for reversal in cases of dysphoria as it does not reverse all of the analgesia. Naloxone, however, is preferred in emergency situations at 0.04 mg/kg IV, IM, SC, or IO. Non-opioid rescue analgesia may be required after reversal using agents such as dexmedetomidine or ketamine.

To conclude the discussion on opioids, it's important to remember a few key points. Butorphanol should never be used as a sole analgesic. Buprenorphine produces less side effects but generally provides less analgesia at standard doses and is best used postoperatively. Methadone is the Goldilocks opioid with its mild side effects and long duration of action. It's important to treat opioid side effects before they occur. Finally, providers should not be hesitant to use opioids. Although they have the potential to cause adverse effects, they are a reliable analgesic class that has been well studied. Opioids should never be used as a sole analgesic in most cases; multimodal analgesia is the standard of care. Practically, this can be also administering an NSAID, using local blocks, and an adjunctive analgesic (ketamine or dexmedetomidine).

Class	Examples	Use	Mechanism
Opioid	Morphine, Butorphanol, Buprenorphine	Varying levels of analgesia and sedation	Reduces excitatory neurotransmitter release in PNS/CNS.
NSAID	Meloxicam, Carprofen, Robenacoxib	Analgesia especially related to inflammation	Inhibits prostaglandin synthesis and decreases inflammatory cell signaling.
NMDA Receptor Antagonist	Ketamine, Tiletamine, Amantadine	Analgesia, general anesthesia	Inhibits glutamate binding in the spinal cord and brain.
Alpha-2 Adrenergic Agonist	Dexmedetomidine, Medetomidine, Xylazine	Analgesia, sedation, anxiolysis	Decreases NE release in the CNS/PNS and acts in the dorsal horn of the spinal cord to inhibit transmission.
Gabapentinoid	Gabapentin, Pregabalin	Anxiolysis, neuropathic analgesia	Blocks Ca^{2+} channels and decreasing Ca^{2+} influx, inhibiting the release of excitatory neurotransmitters.
Benzodiazepine	Diazepam, Midazolam, Zolazepam	Chronic pain, anxiolysis, sedation, anesthesia adjunct	Opens Cl^- channels and causes hyperpolarization of neurons, inhibiting the release of excitatory neurotransmitters.
NK-1 Receptor Antagonist	Maropitant	Antiemetic, mild analgesia, antitussive	Decreases substance-P binding in CNS (especially in the emetic center).
Acetaminophen	Tylenol (Acetaminophen) + Various opioid combinations (classically codeine)	Adjunctive analgesic and antipyretic, especially useful in palliative care.	Inhibits prostaglandin synthesis specifically in the CNS and has no significant anti-inflammatory effect.
Local Anesthetic	Lidocaine, Bupiviciane, Ropivacaine, Mepivacaine	To create total loss of sensation of a targeted region. Lidocaine may be used IV for systemic analgesia in dogs only.	Blocks Na^+ channels causing decreased peripheral neuronal excitability.

Table 3. Classes of analgesics and their uses.

Nonsteroidal Anti-Inflammatory Drugs (NSAIDs)

Nonsteroidal anti-inflammatory drugs (NSAIDs) are a cornerstone of veterinary analgesia, particularly in managing mild to moderate pain associated with inflammation, tissue trauma, or osteoarthritic processes. Their primary mechanism of action involves the inhibition of cyclooxygenase (COX) enzymes, which catalyze the conversion of arachidonic acid into prostanoids, including prostaglandin E_2 (PGE_2), a key mediator of inflammation and pain.

PGE_2 plays a critical role not only in peripheral nociceptor sensitization but also in central pain processing. Within the dorsal horn of the spinal cord, PGE_2 enhances excitatory neurotransmission by promoting the release of glutamate and substance P, and by increasing the excitability of second-order neurons. This contributes to central sensitization, hyperalgesia, and allodynia. By reducing PGE_2 synthesis both peripherally and centrally, NSAIDs attenuate nociceptive transmission and are particularly valuable in multimodal analgesic protocols.

NSAIDs vary significantly in their COX-1 vs. COX-2 selectivity, pharmacokinetics, and safety profiles. COX-1 is constitutively expressed in most tissues and is involved in physiological functions such as gastric mucosal protection, platelet aggregation, and renal blood flow autoregulation. COX-2, by contrast, is inducible and upregulated at sites of inflammation. COX-2–selective inhibitors, such as robenacoxib, deracoxib, and firocoxib, preferentially inhibit inflammatory pathways while sparing COX-1–mediated homeostatic functions, thereby offering a more favorable gastrointestinal and hemostatic safety profile.

From a pharmacokinetic perspective, most veterinary NSAIDs exhibit high plasma protein binding (>98%), resulting in low volumes of distribution and restricted tissue penetration—though they accumulate at sites of inflammation, where local pH and protein extravasation enhance drug retention. Hepatic metabolism is the primary route of elimination, with biliary and/or renal excretion of metabolites. Half-lives vary considerably between species and among NSAIDs. For example, robenacoxib has a notably short plasma half-life in dogs (~1 hour) and cats (~1.1–1.5 hours), yet demonstrates tissue selectivity, persisting in inflamed tissues for up to 24 hours. This allows for once-daily dosing despite rapid plasma clearance. The timing of NSAID administration—pre- vs. post-operatively—has been an area of clinical interest. Preoperative administration is thought to prevent the establishment of central sensitization by blocking early PGE_2 production, potentially improving analgesic outcomes. However, in patients at risk of hypotension, hypovolemia, or renal perfusion deficits during anesthesia, preoperative NSAID use may increase the risk of renal injury due to reduced prostaglandin-mediated afferent arteriolar dilation. In such cases, postoperative administration may offer a safer alternative while still providing effective analgesia.

Robenacoxib (for cats) and carprofen (for dogs) are the preferred perioperative NSAIDs due to favorable safety profile, tissue selectivity, and rapid onset. In patients with stable chronic kidney disease, evidence suggests that a single postoperative dose of a COX-2–selective NSAID, under appropriate monitoring, may be used without significantly increasing the risk of renal decompensation—though this decision must be individualized. Ultimately, NSAIDs remain a foundational component of veterinary analgesia. Their effective and judicious use requires careful attention to pharmacodynamic targets, pharmacokinetic properties, and patient-specific risk factors, particularly when used in the perioperative period.

Opioid Type	Common Examples	Uses	Side Effects
Full-Mu-Agonist	Morphine, Hydromorphone, Fentanyl, Methadone, Meperidine	Profound sedation and analgesia, critically ill patient induction adjunct, epidural analgesia.	Bradycardia, vomiting, diarrhea (then constipation), panting, vocalization, hyperthermia (in cats), dysphoria, ataxia, drooling.
Partial-Mu-Agonist	Buprenorphine	Moderate analgesia and epidural analgesia.	Minimal side effects, mild euphoria, mild sedation, insignificant GI effects, lower risk for bradycardia. .
Agonist/Antagonist	Butorphanol	Mild analgesia (not considered appropriate for intraoperative analgesia).	Constipation, bradycardia, sedation or euphoria.
Antagonist	Naloxone	Emergent opioid reversal.	Excitation after reversal and reverses analgesia, so be prepared with other analgesics.

Table 4. Opioid types, uses, and side effects.

NMDA-Antagonist Anesthetics and Analgesics

N-methyl-D-aspartate (NMDA) receptors are glutamate-gated ion channels that play a central role in nociceptive processing and central sensitization. These receptors are widely distributed throughout the central nervous system, with high concentrations in the dorsal horn of the spinal cord, thalamus, limbic system, and various cortical regions. Under resting conditions, the NMDA receptor channel is blocked by magnesium ions. However, during intense or prolonged nociceptive stimulation—such as that caused by surgical trauma—sufficient postsynaptic depolarization displaces this magnesium block, allowing calcium ions to enter the cell. This calcium influx activates second messenger cascades that contribute to long-term potentiation (LTP), ultimately increasing synaptic efficiency and resulting in the phenomenon of central sensitization, often referred to clinically as “wind-up.”

The administration of NMDA receptor antagonists interrupts this excitatory cascade by blocking the receptor’s ion channel and thereby preventing glutamate-mediated calcium entry. This inhibition reduces neuronal hyperexcitability and attenuates the amplification of nociceptive transmission within the spinal cord and brain. In doing so, NMDA antagonists provide both dose-dependent analgesia and, at higher doses, general anesthesia. Ketamine, the most widely used NMDA antagonist in veterinary medicine, is a noncompetitive blocker of the NMDA receptor and is classified as a Schedule III controlled substance. Its mechanism of action is multifaceted. At subanesthetic doses, ketamine exerts potent antihyperalgesic and analgesic effects primarily through NMDA antagonism. However, at anesthetic doses, it produces a unique state known as dissociative anesthesia, characterized by functional disconnection

between the thalamocortical and limbic systems. This dissociation results from ketamine's suppression of activity in the medial thalamus, which relays sensory information to the cortex, while simultaneously stimulating the limbic system and reticular activating system. The net effect is a cataleptic state in which the patient appears conscious—often maintaining palpebral reflexes and muscle tone—but lacks awareness of the environment and nociceptive stimuli.

The dissociative effects of ketamine are thought to be mediated not only by NMDA antagonism but also by interactions with additional targets, including opioid receptors (particularly κ-opioid receptors), voltage-gated calcium channels, and hyperpolarization-activated cyclic nucleotide-gated (HCN1) channels. Moreover, ketamine modulates monoaminergic neurotransmission by inhibiting reuptake of serotonin, norepinephrine, and dopamine, contributing to both its analgesic and potential antidepressant properties.

In clinical settings, ketamine is frequently employed during anesthetic induction at a dose of 1 to 2 mg/kg intravenously, often in combination with propofol or a benzodiazepine. This approach offers effective preemptive analgesia by preventing central sensitization during the perioperative period. At these doses, ketamine produces minimal cardiovascular stimulation in most patients; however, due to its sympathomimetic effects—including increased heart rate, myocardial oxygen consumption, and systemic vascular resistance—it is typically avoided in animals with pre-existing cardiac conditions such as hypertrophic or dilated cardiomyopathy.

For breakthrough pain management during or after surgery, ketamine may be administered as a bolus at a dose of 0.25 to 0.5 mg/kg intravenously, particularly in patients already receiving opioids. This adjunctive use potentiates analgesic efficacy and is especially beneficial in cases involving severe nociceptive stimuli, such as orthopedic or soft tissue trauma. Continuous rate infusions (CRIs) of ketamine are increasingly utilized in both intraoperative and postoperative settings. These infusions, typically delivered at rates between 2 and 30 µg/kg/min, reduce minimum alveolar concentration (MAC) requirements for inhalants and provide smoother anesthesia. Lower doses in the range of 5 to 10 µg/kg/min are recommended for postoperative pain control, while higher doses are reserved for intraoperative use to achieve MAC-sparing effects. CRIs require careful preparation and administration using a syringe pump, with ketamine diluted to a concentration of 5 to 10 mg/mL to ensure accurate and consistent delivery. Despite ketamine's relatively short half-life in dogs

—approximately one hour—its effects are sustained during continuous infusion due to steady plasma concentrations and central receptor occupancy.

In chronic or refractory pain states, subcutaneous administration of ketamine has been explored as an off-label approach. Anecdotal protocols suggest that a single subcutaneous dose of 0.5 mg/kg may provide prolonged relief by transiently reversing central sensitization and restoring normal nociceptive thresholds within the spinal cord. However, the pharmacokinetic profile of ketamine does not support sustained systemic exposure following subcutaneous injection, and any prolonged analgesic benefit is more likely attributable to its transient neuromodulatory effects on spinal excitability than to persistent drug presence. Further research is needed to clarify the clinical validity and mechanism of this route.

Tiletamine, a dissociative anesthetic structurally related to ketamine, is available exclusively in combination with the benzodiazepine zolazepam in the commercial formulation Telazol®. Like ketamine, tiletamine is a Schedule III controlled substance and is used for chemical restraint and anesthetic induction in veterinary species. Amantadine, by contrast, is a noncontrolled, orally administered agent with weak NMDA antagonist activity. Though its receptor binding affinity is significantly lower, amantadine has demonstrated utility as an adjunct in chronic or neuropathic pain management, particularly when combined with nonsteroidal anti-inflammatory drugs (NSAIDs) or opioids. Its primary therapeutic role lies in disrupting the maintenance of central sensitization, thereby enhancing the efficacy of concurrent analgesics.

In summary, NMDA receptor antagonists—particularly ketamine—represent a vital component of multimodal analgesic strategies in veterinary practice. By preventing or reversing central sensitization, these agents reduce both acute and chronic pain, spare inhalant and opioid requirements, and modulate nociceptive pathways at multiple levels of the central nervous system. A comprehensive understanding of their mechanisms, pharmacokinetics, and systemic effects is essential for their safe and effective use in clinical anesthesia and pain management.

Alpha$_2$ Adrenergic Receptor Agonists

Norepinephrine (NE) is a key excitatory neurotransmitter in both the central and peripheral nervous systems, contributing to arousal, vigilance, cardiovascular tone, and pain modulation. Its release and synaptic concentration are tightly regulated by a family of adrenergic receptors, which are G protein-coupled receptors (GPCRs) classified broadly into

alpha (α) and beta (β) subtypes. Among these, the alpha-2 adrenergic receptor (α_2-AR) plays a particularly important role in negative feedback regulation of norepinephrine release.

Alpha-2 receptors are located presynaptically in the central nervous system (CNS) and postsynaptically in peripheral tissues, including vascular smooth muscle. On presynaptic neurons, α_2-ARs function as autoreceptors. When NE is released into the synaptic cleft, it binds to these receptors, triggering a Gi-protein-mediated inhibition of adenylate cyclase, which decreases intracellular cAMP levels and inhibits calcium influx. This suppresses further exocytosis of NE vesicles, forming a negative feedback loop that reduces ongoing norepinephrine release and dampens excitatory transmission. Postsynaptically, particularly in vascular smooth muscle, α_2-AR activation leads to vasoconstriction via inhibition of potassium channels and enhanced calcium entry. Alpha-2 adrenergic agonists exploit this negative feedback mechanism by mimicking endogenous NE at the α_2 receptor, thereby reducing central norepinephrine release and decreasing sympathetic outflow. This pharmacologic action results in dose-dependent sedation, anxiolysis, muscle relaxation, and analgesia, the latter of which is mediated primarily within the dorsal horn of the spinal cord. In the context of analgesia, α_2 agonists enhance inhibitory interneuron activity and diminish the release of excitatory neurotransmitters such as substance P and glutamate. Their analgesic effect is considered synergistic when combined with opioids or NMDA receptor antagonists, making them a valuable component of multimodal analgesic strategies.

In veterinary practice, commonly used α_2 agonists include xylazine, detomidine, medetomidine, and dexmedetomidine. Of these, dexmedetomidine—the dextrorotatory enantiomer of medetomidine—is the most selective and widely employed in small animal medicine due to its predictable pharmacokinetics and relatively favorable side-effect profile. Dexmedetomidine is characterized by high α_2-to-α_1 receptor selectivity (~1600:1), which enhances sedative and analgesic effects while minimizing peripheral adrenergic stimulation.

The cardiovascular effects of dexmedetomidine are well-documented and biphasic. Initially, stimulation of peripheral postsynaptic α_2 receptors on vascular smooth muscle induces vasoconstriction, leading to an increase in systemic vascular resistance (SVR) and mean arterial pressure (MAP). This rise in arterial pressure triggers a compensatory baroreceptor-mediated bradycardia, which may be profound but typically resolves as vasoconstriction wanes. Following this hypertensive phase—lasting approximately 30 to 45 minutes depending on dose and route of

administration—a modest decline in blood pressure may ensue due to central sympatholytic effects and reduced cardiac output. Dexmedetomidine also decreases myocardial contractility by impairing β-adrenergic stimulation and altering calcium dynamics in cardiomyocytes, which contributes to reduced inotropy and overall cardiac output. Additionally, the drug is associated with dose-dependent alterations in atrioventricular (AV) conduction, commonly resulting in first- or second-degree AV blocks, which are typically benign but may warrant intervention in compromised patients. Due to these hemodynamic effects, dexmedetomidine is contraindicated in patients with significant cardiovascular disease, particularly those with mitral or tricuspid regurgitation, where increased afterload and decreased cardiac output may exacerbate underlying pathology.

Reversal of dexmedetomidine is achieved with atipamezole, a selective α_2-adrenergic antagonist. When administered intramuscularly, atipamezole reverses sedation and analgesia within minutes. Intraoperative or intravenous use requires caution; slow IV administration over 5 to 10 minutes is recommended to avoid abrupt sympathetic rebound, which may precipitate profound hypotension or reflex bradycardia.

Clinically, the labeled dosage of dexmedetomidine is considerably higher than what is typically used in modern veterinary practice. For routine premedication in dogs, doses of 2–5 μg/kg IM are commonly employed in combination with an opioid. Intravenous administration allows for dose reduction due to greater bioavailability (~30% higher), with effective doses often ranging from 1–3 μg/kg IV. For procedural sedation, higher doses—up to 10 μg/kg IM or 7 μg/kg IV—may be used in conjunction with opioids and/or ketamine to achieve deeper sedation while preserving spontaneous ventilation and hemodynamic stability in healthy patients.

In recent years, dexmedetomidine microdosing has gained popularity for adjunctive intraoperative and postoperative use. Doses as low as 0.25 to 1 μg/kg IV have been shown to provide short-term (15–30 minutes) analgesia, MAC-sparing effects, and control of postoperative dysphoria. This approach enables reduction in opioid use while maintaining patient comfort. Furthermore, dexmedetomidine CRIs, typically ranging from 0.25 to 2 μg/kg/hr, offer sustained sedation and analgesia in the ICU or recovery setting. Higher infusion rates may be utilized intraoperatively for MAC-sparing or during mechanical ventilation but require careful hemodynamic monitoring due to potential cumulative cardiovascular depression.

In summary, α_2-adrenergic agonists—particularly dexmedetomidine—offer a powerful combination of sedation and analgesia through central suppression of norepinephrine release. Their use must be tailored to each patient's cardiovascular status, with dose optimization and reversal strategies in place. When integrated thoughtfully into balanced anesthetic protocols, dexmedetomidine enhances perioperative comfort, reduces anesthetic requirements, and contributes to effective multimodal analgesia in small animal patients.

GABAergic Drugs

Gamma-aminobutyric acid (GABA) is the principal inhibitory neurotransmitter in the mammalian central nervous system (CNS), playing a crucial role in the modulation of excitability, arousal, and pain perception. Two primary drug classes target GABA-related mechanisms in clinical and veterinary medicine: GABA receptor agonists and gabapentinoids. Although both contribute to anxiolysis and analgesia, they act through distinct molecular mechanisms and are pharmacologically unrelated in terms of receptor binding.

GABA Receptor Agonists

GABA exerts its inhibitory effects via two main receptor types: $GABA_A$ and $GABA_B$. The $GABA_A$ receptor is a ligand-gated chloride ion channel widely expressed in the brain, including regions involved in nociception and emotional regulation such as the thalamus, hippocampus, hypothalamus, medulla, and spinal dorsal horn. When GABA binds to the $GABA_A$ receptor, chloride influx occurs, resulting in hyperpolarization of the postsynaptic membrane and reduced likelihood of neuronal firing. This effect leads to widespread CNS depression, which manifests clinically as sedation, anxiolysis, muscle relaxation, and hypnosis depending on the drug's specificity and dose.

Several drug classes, including benzodiazepines and general anesthetics, act as positive allosteric modulators at the $GABA_A$ receptor. Benzodiazepines, such as diazepam and midazolam, enhance the frequency of chloride channel opening in the presence of GABA, thereby potentiating inhibitory neurotransmission. These drugs do not directly activate the receptor but instead require endogenous GABA for their effect, which explains their ceiling on CNS depression and their relative safety compared to other sedatives. Benzodiazepines are commonly used in veterinary medicine for their anxiolytic, muscle relaxant, and anticonvulsant properties but lack intrinsic analgesic activity. However, they may

indirectly reduce pain perception through central sedation and anxiolysis, especially in acute distress states or during procedural sedation.

In contrast, some general anesthetics such as propofol, alfaxalone, and inhalants (e.g., isoflurane, sevoflurane) act at different sites on the $GABA_A$ receptor to potentiate chloride conductance more robustly, often without the need for GABA co-binding. These agents can cause profound CNS depression, hypnosis, and immobility, forming the pharmacologic basis of general anesthesia. However, their contribution to analgesia is minimal to absent; therefore, they are NOT considered analgesic drugs in isolation.

Gabapentinoids

Gabapentin and pregabalin are structural analogs of GABA but do not act on GABA receptors. Instead, they exert their pharmacologic effects by binding to the α2δ-1 subunit of presynaptic voltage-gated calcium channels (VGCCs), particularly the P/Q-type and N-type calcium channels. These channels are widely expressed on excitatory neurons, including those in the spinal dorsal horn, dorsal root ganglia, and brainstem nuclei involved in nociception. Under normal conditions, depolarization of presynaptic neurons triggers the opening of calcium channels, allowing calcium influx that facilitates vesicular release of excitatory neurotransmitters—most notably glutamate and substance P.

Gabapentinoids bind to the α2δ-1 subunit of these channels, reducing calcium influx and thereby inhibiting presynaptic neurotransmitter release. The result is decreased neuronal excitability and a reduction in the amplification of nociceptive signaling. Although the exact mechanisms remain under investigation, these agents are particularly effective in states of central sensitization and neuropathic pain, where upregulation of α2δ subunits and altered synaptic plasticity contribute to ongoing pain independent of peripheral nociceptive input.

Gabapentinoids do not possess significant efficacy in treating acute nociceptive pain when used alone. However, they are often employed as adjuncts in multimodal analgesic protocols, particularly in chronic pain syndromes, neuropathic conditions, osteoarthritis, and cancer-related pain. Their synergy with opioids and NSAIDs allows for opioid-sparing effects and improved analgesic control, especially in refractory pain states.

Clinically, gabapentinoids are frequently used to attenuate central sensitization or prevent “wind-up” phenomena, particularly in chronic or maladaptive pain states. Wind-up refers to the progressive, activity-dependent increase in the excitability of spinal dorsal horn neurons in

response to sustained nociceptive input. Over time, such stimulation may lead to structural and functional changes in the nervous system, including synaptic remodeling and ectopic discharge generation, contributing to the development of neuropathic pain. Gabapentinoids may help prevent or reverse these changes by dampening afferent input and decreasing neuronal excitability, although the full scope of their neuroplastic effects remains under investigation.

Despite their utility, gabapentinoids should be used with caution in perioperative settings. Sedation, ataxia, and mild gastrointestinal upset are among the most common adverse effects. Additionally, abrupt discontinuation—particularly after chronic administration—may result in rebound excitability, including seizures in predisposed patients. For this reason, tapering is recommended after long-term use.

In summary, while GABA receptor agonists and gabapentinoids both contribute to modulation of central excitability, they do so via distinct mechanisms. GABA agonists such as benzodiazepines and anesthetics directly enhance chloride conductance through $GABA_A$ receptors, producing sedation and anxiolysis, but not intrinsic analgesia. In contrast, gabapentinoids act presynaptically on calcium channels, reducing glutamate release and playing a key role in the treatment of chronic and neuropathic pain. When integrated into a multimodal approach, both classes support improved patient comfort and may contribute to reduced opioid dependence, enhanced recovery, and better long-term pain management outcomes.

Neurokinin-1 Antagonists

Maropitant citrate, commonly known by its trade name Cerenia, is a selective antagonist of the neurokinin-1 receptor (NK-1R), a G-protein coupled receptor widely expressed in both the central and peripheral nervous systems. The endogenous ligand for NK-1R is substance P, a neuropeptide involved in transmitting nociceptive, emetic, inflammatory, and autonomic signals. Substance P is predominantly localized in brain regions implicated in vomiting, pain modulation, and inflammatory processes, including the area postrema, nucleus tractus solitarius (NTS), spinal dorsal horn, and peripheral sensory neurons.

Upon binding to NK-1R, substance P initiates intracellular signaling cascades that promote excitatory neurotransmission and neurogenic inflammation. This leads to several physiological effects, including activation of the vomiting reflex, facilitation of pain transmission, vasodilation, and modulation of immune cell activity. By competitively

antagonizing NK-1R, maropitant effectively inhibits substance P binding, thereby attenuating these downstream effects.

Pharmacodynamically, maropitant's principal veterinary indication is as a potent antiemetic, attributed to the high density of NK-1 receptors within the chemoreceptor trigger zone (CTZ) and emetic centers of the medulla oblongata. Blockade of these receptors prevents emetic signaling, making maropitant highly effective in preventing and treating nausea and vomiting from a variety of causes, including motion sickness, chemotherapy, and perioperative anesthesia.

Beyond its antiemetic properties, maropitant has demonstrated analgesic effects, particularly in visceral pain. Substance P is a key neurotransmitter in the transmission of nociceptive signals within the spinal dorsal horn, especially in the context of inflammatory and visceral pain syndromes. By inhibiting NK-1R-mediated transmission, maropitant reduces central sensitization and may blunt nociceptive input, thereby contributing to dose-dependent analgesia. Although maropitant is not a primary analgesic, it can serve as an adjunct in multimodal pain management protocols, especially for visceral discomfort or inflammatory conditions. Some clinical and experimental evidence suggests that maropitant may also possess mild sedative effects due to NK-1 receptor blockade in CNS regions involved in arousal and autonomic regulation.

Pharmacokinetically, maropitant is available in both injectable and oral formulations, with distinct absorption profiles. Following subcutaneous or intravenous administration, maropitant reaches peak plasma concentrations rapidly (within 30–60 minutes) and has a relatively long elimination half-life of approximately 6–8 hours in dogs and cats. The drug is extensively metabolized by hepatic cytochrome P450 enzymes and eliminated primarily via biliary excretion. Oral bioavailability varies between species and formulations but is generally high, although injectable maropitant is preferred perioperatively to ensure prompt and consistent plasma levels, which may enhance its central effects.

Clinically, the use of injectable maropitant prior to anesthesia induction not only prevents anesthesia-associated nausea and vomiting but may also confer ancillary benefits in reducing visceral pain and stress responses. This makes it a valuable component in enhanced recovery protocols and multimodal analgesia strategies. Additionally, maropitant's NK-1 receptor antagonism modulates inflammatory cell proliferation and may have secondary effects on endocrine and paracrine signaling pathways, though these effects remain less well-characterized in veterinary patients.

In summary, maropitant is a highly selective NK-1 receptor

antagonist whose principal clinical utility lies in its antiemetic efficacy. However, its blockade of substance P transmission within the CNS and peripheral nervous system also confers dose-dependent analgesic, sedative, and potential anti-inflammatory effects. The drug's favorable pharmacokinetic profile and multipurpose utility make it a valuable adjunct in veterinary anesthesia and pain management.

Local Anesthetics

The final major receptor family of significance in veterinary analgesia encompasses the voltage-gated sodium ion channels. located on peripheral nerve axons. These channels are integral to the generation and propagation of the neuronal action potential, allowing for the influx of sodium ions during depolarization. The initiation of an action potential depends critically on the rapid opening of these channels, which depolarizes the neuronal membrane and propagates electrical impulses along the nerve fiber. When these sodium channels are pharmacologically blocked, sodium influx is inhibited, thereby preventing membrane depolarization and the conduction of nociceptive signals from the periphery to the central nervous system. This mechanism underlies the analgesic and anesthetic properties of local anesthetics.

Local anesthetics such as lidocaine, bupivacaine, mepivacaine, and ropivacaine exert their effects by binding to specific sites on the intracellular portion of voltage-gated sodium channels, preferentially stabilizing the channel in its inactive state. This blockade is use- and state-dependent; it is more effective on rapidly firing or depolarized neurons, which explains the selectivity for nociceptive fibers during painful stimuli. The onset and duration of action of each local anesthetic vary due to differences in lipid solubility, protein binding affinity, and pKa, influencing clinical applications. For instance, lidocaine has a rapid onset but shorter duration, whereas bupivacaine and ropivacaine provide longer-lasting anesthesia suitable for prolonged procedures or postoperative analgesia.

A critical distinction in the use of local anesthetics lies between local infiltration or nerve blocks and systemic administration. Of these agents, lidocaine is the only local anesthetic commonly utilized systemically in veterinary medicine, primarily in canine patients, for its antiarrhythmic and analgesic properties. Systemic administration of other local anesthetics, particularly bupivacaine, is contraindicated due to their narrow therapeutic index and potential for severe central nervous system (CNS) toxicity and cardiotoxicity, including seizures, arrhythmias, and cardiovascular collapse. Thus, careful dose calculation and monitoring are imperative

during clinical use.

Local anesthetics are among the most effective agents for managing acute perioperative pain, as they prevent nociceptive input at its origin, effectively reducing central sensitization and subsequent chronic pain development. Clinically, local anesthetics are administered via several modalities including peripheral nerve blocks, epidural injections, and local infiltration techniques. Peripheral nerve blocks—such as sciatic, femoral, and various dental nerve blocks—have gained increasing traction in general practice due to their specificity and opioid-sparing effects, though adoption remains limited in some settings due to insufficient practitioner training or equipment availability.

Epidural administration of local anesthetics offers potent analgesia by directly targeting the dorsal nerve roots and spinal cord, providing a regional anesthetic effect that can be tailored to the surgical site and patient needs. Local infiltration, including pre-incisional line blocks, is a simple yet effective technique commonly underutilized in general practice; even small volumes of local anesthetic administered prior to skin incision can significantly reduce perioperative nociception, especially in procedures involving the abdomen or thorax.

Postoperative use of local anesthetics via infiltration or continuous infusion is also clinically valuable. However, infiltration after tissue closure carries an increased risk of systemic absorption due to trauma-induced capillary disruption, which can lead to elevated plasma concentrations and potential toxicity. To address this, continuous local anesthetic delivery via soaker catheters placed within surgical sites has emerged as an advanced technique. These catheters allow for controlled infusion of local anesthetics over several days postoperatively, providing sustained analgesia for extensive procedures such as large tumor resections or thoracotomies. This approach not only improves patient comfort but may also reduce reliance on systemic opioids and their associated side effects.

In conclusion, local anesthetics targeting voltage-gated sodium channels are an essential pillar of multimodal analgesia in veterinary medicine. Their unique mechanism of action permits effective blockade of peripheral nociceptive transmission, making them invaluable for both intraoperative and postoperative pain control. Despite their proven efficacy, local anesthetics remain underutilized in many general practices, highlighting the need for enhanced education and training in regional anesthesia techniques to improve patient outcomes.

Constant Rate Infusions

Troubleshooting analgesia in longer or more painful procedures can be difficult. One way to eliminate gaps in analgesia is the use of a constant rate infusion (CRI). CRIs provide a steady and adjustable plane of analgesia. As the name implies, CRIs utilize analgesics delivered at a *constant rate*. This prevents peaks and valleys in plasma levels of an analgesic. Generally, CRI's utilize a drug's pharmacokinetics to ideally stabilize the plasma levels and rely on being excreted at the same rate its being delivered. This usually requires a loading dose to initially raise the plasma levels of a drug. Simply put, this allows the drug to maintain a steady level in the patient's system and provides steady effects. This effect can easily be titrated up or down using a syringe pump. In the general practice setting, CRIs are widely administered via dilution or as an additive to IV fluids. It is important to note that other drugs can be used in CRIs, not just analgesics, such as metoclopramide and insulin.

Chapter 2
Anesthetic Monitoring and Pertinent Physiology

Assessing Anesthetic Depth

Monitoring each anesthetic patient is crucial to a safe and balanced anesthesia. Modalities of ensuring proper anesthetic monitoring include assessing anesthetic depth, monitoring vital signs and hemodynamics, and assessing volemic status.

Assessing anesthetic depth is the first pillar of safe anesthesia and perhaps one of the most advantageous. Adequate anesthetic depth ensures patient safety and comfort, minimizes surgical complications, and ensures staff safety. The goal of anesthetic maintenance is to keep a patient unconscious and pain-free with minimal changes to normal physiologic functions. Determining what plane of anesthesia a patient is in requires a skillful eye and vigilance. There are several factors that one may assess to gauge depth [**Table 5]**. One of the most reliable parameters is the palpebral and auricular reflexes. The palpebral reflex is most accurate in the canine patient, as cats' palpebral reflex can be slightly unreliable. This involves tapping the medial canthus of the eye to elicit a blink response. A quick blink indicates the patient is too light. A slow or slightly absent blink means adequate anesthetic depth. No reflex, as well as other signs of being heavily anesthetized, can be indicative of a patient being too deeply anesthetized. The auricular reflex is most accurate in feline patients. This reflex involves blowing into or tickling a cat's inner pinna. Adequately anesthetized feline patients should have no response to said stimuli. Generally, cats may be extubated upon swallowing or flicking their tongue. While with dogs several movements must be observed prior to extubation, cats may be extubated earlier once they begin showing signs of airway tone. Delayed extubation in cats increased risk of tracheal and laryngeal trauma.

	Depth		
Parameter	**Light**	**Ideal**	**Deep**
Eye Position	Central	Rotated ventromedially	Central
Nictitans Position	Relaxed	Partially covering eye	Covering eye
Palpebral Reflex Response	Present	Minimal	Absent
Muscle (Jaw) Tone	Tense	Loose	Loose
Pupil Reactivity	Normal	Sluggish	Very slow or absent
Response to Surgery	Sudden ↑ HR, maybe BP	Minimal or no ↑ HR/BP	Absent response
Hemodynamic Status	↑ HR, maybe BP	Normal HR and BP	↓ HR and BP
Respiration Rate (rpm)	>12	8-12	<8

Table 5. The parameters for assessing anesthetic depth.[10] Although reliable parameters, these should never be used solely to assess anesthetic depth.

Another accurate parameter to access anesthetic depth is eyeball position. The muscles that control the eyeballs are relaxed via decreased neurological signals coming from the cranial nerves. Both cats' and dogs' eyes should be rotated slightly medioventral. The more rotated the eye appears (i.e., the more white that's visible), the deeper the patient is. When patients are too light, their eye position will look as if they are awake. The eyeball becomes straight in a normal position; very deep anesthesia can also show this sign. Also an indicator in the eyes is the position of the nictitating membrane, or the nictitans. The nictitans, commonly referred to as the "third eyelid" is a pink membrane that, when anesthetized, relaxes to various degrees. While sometimes unreliable, the more cranial the nictitans extends, the more relaxed or deep the patient is. The more receded the nictitans, the lighter and more awake the patient.

Jaw tone is a reliable indicator of anesthetic depth. The masseter muscle is the strongest muscle in the body. In a healthy and awake patient, one would meet muscular resistance when attempting to pry open a dog or cat mouth. When anesthetized, the jaw muscles greatly relax and allow the jaw to freely open to a certain extent. To test jaw tone, place your thumb over the lateral surface of your index finger on the same hand to form a cross shape. Place the tips of your thumb and index finger on the tips of the patient's teeth. Only put as much of your fingers in the mouth as necessary to apply very gentle opposing pressure. With very slight pressure, attempt to pry open the jaws by opposing your thumb and your index finger. This method nearly eliminates subjectivity. Testing jaw tone by using your

hands to open the jaw uses much greater amounts of force that can seem as though the jaw is loose.

The final physical assessment for anesthetic depth is the pupillary light reflex (PLR). This describes a patient's autonomic reflex to stimuli—an indirect measure of patient depth. Using a pen light, expose the eye to light for 1-2 seconds and observe the speed (or if it occurs at all) at which the pupil constricts. The slower the pupil constriction, the deeper an anesthetic plane. The resting pupil size is also helpful in determining autonomic tone. The more dilated the pupils remain, the deeper anesthetic plane the patient is in. The more constricted a patient's pupils become , the lighter the anesthetic plane. A very large, or dilated, pupil indicated too deep of an anesthetic plane especially if the pupil becomes unresponsive to light. Some injectable anesthetics and analgesia (ex. opioids) cause mydriasis, or widening of the pupil, but generally do not impact PLRs.

Vital signs tell the anesthetist real-time quantitative and qualitative information regarding their patient. There are several parameters relevant to monitoring anesthesia including heart rate, respiration rate, oxygen saturation (SpO_2), blood pressure, $ETCO_2$, temperature, mucous membrane color and moisture level, and more. For the most part, tolerable vital signs should not differ much from non-anesthetized expected values. For example, a canine patient with a normal resting heart rate of 90 beats per minute, when anesthetized, should not differ much from 90 bpm. However, various vital parameters can be altered by drugs or pathologies. It is crucial for the anesthetist to understand physiologic changes that can result from the agents they are using. A critical example of this is dexmedetomidine (DexDomitor) use. Because it falls into the alpha-2 drug class, it causes increased peripheral vasoconstriction, leading to increased afterload. This in turn causes varying levels of reflex bradycardia. Some canine patients may have extreme bradycardia (i.e., <50 bpm) and extreme hypertension (MAP >100 mmHg). This is tolerable with the use of dexmedetomidine because this is a compensatory mechanism. An untrained or inexperienced anesthesia may not recognize this and provide unnecessary and potentially harmful interventions. Anesthesia and associated agents most often than not cause some degree of physiologic changes.

Both respiratory rate and heart rate are good indicators of sympathetic activity. Anesthetized patients should be breathing about 8-12 times per minute. Slightly less and slightly more can be tolerable depending on the patient and drugs used. A panting patient is very light and may even be feeling surgical stimulation (pain). A patient with a respiratory rate of less than 7-8 indicates too deep of an anesthetic plane.

End-tidal carbon dioxide ($ETCO_2$) is the quantified amount of exhaled carbon dioxide, which is an indirect indicator of respiratory, perfusion, and cellular metabolic status. Capnography is the device that measures and displays the amount of exhaled CO_2. Carbon dioxide (CO_2) when dissolved in blood, is in the form of carbonic acid, which dissociates into water and CO_2 during gas exchange in the lungs. Blood pH is therefore determined partially by carbon dioxide. Hypocapnia (decreased $ETCO_2$) can be indicative of several things (hyPERventilation, hypometabolic state, impending cardiac arrest, single lung intubation) but is useful in determining respiratory status. Much like respiration rate, heart rate can provide great information about the depth of the patient. Obviously, all patients have different resting heart rates, and anesthetic agents greatly vary in terms of normal rate. After obtaining a baseline heart rate, any increases can indicate the patient is becoming light and feeling the surgical stimulation. Any decrease in heart rate may lead to changes in hemodynamic stability and intervention with an anticholinergic or sympathomimetic may be necessary.

Electrocardiogram (ECG)

An ECG is a crucial tool in anesthesia. ECG can be measured and interpreted using several different lead systems (3, 4, 6, or 12); the electrodes sense the electrical conduction, directionality, and amplitude in the myocardium. A monitor displays this reading from various angles depending on the number of physical leads. In the 3-lead ECG, there are subsequently leads to choose to display. Each lead shows a different angle of the heart, depending on where on the body the lead is placed. Most veterinary monitors provide diagnostic level ECG's. Even if the monitor does show a high-quality waveform, individual waves and lengths can still be discerned.

Firstly, one must understand how the electrical currents flow through the heart. The sinoatrial (SA) node is also called the "natural pacemaker," as all normal electrical impulses originate from this bundle of neurons. This node resides in the cranial aspect of the right atrium. The electrical impulses then move through the atria walls via the internodal pathways to reach the atrioventricular (AV) node, which is appropriately positioned between the atria and the ventricles. During this transfer of electricity, the nerves depolarize, releasing their potential energy into the atrial myocytes. This causes the atria to contract. From there, the impulses travel through the Bundle of His (located in the ventricular septum) and to the purkinje fibers (PF). At this point, the depolarization of the PF traveling through the

ventricular walls causes the ventricles to contract. During depolarization, sodium ions (Na+) rush into the neurons, while potassium ions (K+) leave the cell. This interaction is called a membrane potential. The membrane potential is determined by the relative balance of these ions across the membrane of the myocardiocytes. .

An ECG records the net movement of electricity through the heart. Each wave of a single cycle represents either depolarization (contraction) or repolarization (relaxation) of cells in the heart. The first wave is the ECG is the P wave, representing atrial depolarization (followed by atrial contraction). Next, the QRS complex represents the largest electrical change in the cardiac cycle, ventricular depolarization (followed by ventricular contraction). Lastly, the T wave represents ventricular repolarization (followed by ventricular relaxation—specifically membrane potentials "reloading" for the next depolarization). Atrial repolarization is not readily seen on an ECG as it happens directly before the QRS complex, which is a much larger change in energy than the atria repolarize. Therefore, technically it is present but not seen due to the large amount of energy produced by the QRS.

The QRS complex represents ventricular depolarization; in a healthy patient, each QRS should correlate to a pulse beat. When monitoring an anesthetic patient, it is important to trust the monitors being used. One way to verify validity of a displayed heart rate is to auscultate heart sounds and ensure they match the QRS complexes shown. It is important to note that in cases of pulseless electrical activity (PEA), the ECG may appear normal but in fact the patient is in cardiac arrest. Careful monitoring of pulses and the pulse oximeter pleth allow the anesthetist to monitor true pulsatile correlations to the ECG. Like previously mentioned, the average veterinary anesthesia ECG is not designed to be diagnostic. In other words, most cannot accurately show precise waves and lengths. With that being said, the average ECG machine should allow an anesthetist to identify obvious electrical pathologies including an AV block, fibrillation, and asystole.

Simply put, an AV block is an issue with the electrical pathway between the SA and the AV nodes. This means the AV node does not receive information from the SA node. The AV node can generate an electrical impulse on its own, typically not exceeding 60 bpm. A second degree AV block is the most common under anesthesia and can be induced by several drugs including dexmedetomidine. On an ECG, a second degree AV block presents as a P wave (atrial depolarization from the SA node) without a following QRS complex. Conceptually, this makes sense as the electrical impulse from the SA never reaches the AV node (i.e., the

ventricles don't contract from that impulse).

Another important pathology potentially seen on an ECG is fibrillation. Fibrillation is uncoordinated depolarization of the cells in the heart causing irregular movement that does not move blood. Atrial fibrillation is this occurring in the atria, which can affect preload and increase chance of a clot forming due to stagnation of blood in the atria. Atrial fibrillation (AF) is a common, chronic pathology. AF is an irregular rhythm with no discernible P wave in which the atria quiver due to erratic signalling. In contrast, ventricular fibrillation (VF) is an acute heart rhythm that is associated with cardiac arrest. This rhythm is almost always fatal. On ECG, VF presents as an erratic tracing with no defined waves. When this rhythm is recognized, immediate defibrillation is indicated. If no defibrillator is available, cardiac compressions must be initiated immediately to maintain perfusion, as this rhythm does not pump blood. Treatment for this rhythm is electrical defibrillation. Antiarrhythmics like amiodarone and lidocaine may be used for VF refractory to defibrillation. Both work by blocking sodium/potassium pumps in the cardiac myocytes to slow the transferring of ions over the membrane. This stabilizes the membrane potential which decreases overall excitability of the cell. This *calming* effect is advantageous in normalizing electrical conduction in the heart's pathways. Another way is mechanical cardioversion, which includes external or internal defibrillation. This, however, is typically not accessible in a general practice setting.

Hemodynamics and Perfusion

Hemodynamic function is the interaction between various components of the cardiovascular system and function. These components include heart rate/heart contractility (cardiac output) and vasodilation/ constriction. Think of this as the pump (the heart) and the pipes (the blood vessels) resulting in a given flow pressure (blood pressure). The net perfusion of the combined components produces hemodynamics. Maintaining the patient's hemodynamic stability is a critical aspect of maintaining general anesthesia. If a patient had irregular heart rhythms, hypotension, or poor oxygenation (low SpO_2), that patient is considered hemodynamically unstable. This can lead to forms of shock (inadequate perfusion). Because of this, it is vital to monitor hemodynamics. The hemodynamic status of a patient is crucial to safe anesthesia. If a patient becomes hemodynamically unstable, the anesthetist must think critically to treat the affected aspect of the cardiovascular system.

An important pillar of hemodynamics is volemic status or volume

status. This refers to any losses of volume (blood loss, preoperative vomiting/diarrhea/overall dehydration, patients on diuretics) and any addition of volume (IV fluids/SQ fluids). Volume status is imperative to monitor because hypovolemia and fluid overload are both considered anesthetic complications and can increase the risk of further complications or even death. Dehydration or hypovolemia is an inadequate amount of intravascular fluid (often blood but can also be fluids and blood products), resulting in hypoperfusion (shock). Fluid overload is an excess amount of intravascular fluid, causing fluid to leave the intravascular space and move into the extravascular/interstitial spaces. This can cause widespread edema including pulmonary edema, which, if not identified and treated early, can lead to death in an anesthetic patient. Assessing fluid status uses various parameters, including blood pressure, mucous membrane moisture level, skin turgor, and urine output. Increased fluid volume (if severe) can be treated with furosemide to diurese extra fluid out). Decreased fluid volume is treated with the addition of fluids.

Hypotension [**Figure 1**] is one of the most common anesthetic complications due to many anesthetic agents causing vasodilation, negative inotropy (decreased heart contractility strength), and chronotropy (decreased heart contractility rate, prompting bradycardia). Mean Arterial Pressure (MAP) is used as a universal blood pressure parameter. Hypotension is defined by MAP <60 mmHg, while hypertension is defined by MAP >120 mmHg. Hypotension is usually an acute (but can be chronic) pathology that can result in hypoperfusion of vital organs such as the brain, heart, and kidneys. Broadly speaking, acute hypertension is less dangerous and is typically secondary to other pathologies. In an acute anesthetic context, hypertension may cause ischemia or hemorrhage of various regions of the body and increase the risk of surgical complications. However, in anesthesia, hypotension is much more serious and can cause acute kidney injury (AKI), ischemic brain injuries or heart pathologies, and more conditions related to hypoperfusion.[20] Hypertension may be seen as a side effect from vasoconstricting medication such as dexmedetomidine or ketamine. Sudden hypertension with bradycardia may be indicative of increased intracranial pressure, known as the Cushing's Reflex.

There are several mechanisms that mediate hypotension. Blood pressure (BP) is a product of cardiac output (CO) multiplied by systemic vascular resistance (SVR); BP = CO x SVR. Cardiac output is the product of stroke volume (SV) multiplied by the heart rate (HR); CO= SV x HR. Stroke volume is the amount of blood ejected by the left ventricle during each contraction. SVR is the degree of vasoconstriction or vasodilation

present in systemic circulation, also called afterload. In summary, any of the previously mentioned factors can influence blood pressure. For example, if cardiac output and/or SVR are low, blood pressure may be low when BP = CO x SVR. Because CO = HR x SV, if CO is low, HR or SV may be mediating this decrease. This is where tolerability of heart rate intersects. A low heart rate may not be problematic if tissue perfusion remains adequate. Generally, if blood pressure is adequate, if peripheral pulses may be easily palpated, if mucous membranes remain moist and pink, and if respiratory status remains adequate, sinus bradycardia may be tolerated. When heart rate is low, blood vessels may experience reflex vasoconstriction to compensate for the decreased cardiac output. When referencing the blood pressure equation, if cardiac output decreases, SVR may increase by reflex to hold blood pressure constant. The same proportionality rule applies to CO= SV x HR; if heart rate is low, and blood pressure is low, the hypotension may be a result of decreased cardiac output (via low HR) and therefore lowers blood pressure. By increasing the heart rate, blood pressure may improve via increased CO. This is advantageous in cases where hypotension is accompanied by bradycardia; see **Figure 1**.

Because hypotension is more of a concern in an anesthetic context, most anesthetists focus on keeping MAP >65 mmHg and do not worry much about keeping the MAP <120 mmHg. Some examples of agents that cause hypotension are acepromazine (via vasodilation), propofol (via vasodilation), dexmedetomidine (via vasodilation after initial vasoconstriction and decreased cardiac output), and isoflurane (via profound vasodilation), among many other agents. Hypotension can be dangerous in any patient due to inadequate perfusion. Patients especially at risk of inadequate perfusion are geriatric patients, those with cardiovascular or metabolic disease, and trauma patients. Treating anesthetic hypotension requires a multimodal approach.

Tachycardia may be present with hypotension. This is considered a state of compensation. Because blood pressure is low, the body increases heart rate to try to keep stroke volume constant; Blood Pressure= CO x SVR. If SVR is low, the HR will increase to attempt to raise BP. Generally, when blood pressure increases, heart rate decreases (due to the baroreceptor reflex); when blood pressure decreases, heart rate increases. An important note is that propofol, a commonly vasodilating anesthetic, inhibits this reflex. Therefore, reflex tachycardia is almost never seen with propofol mediated hypotension. However, another common hypnotic induction agent, alfaxalone, does not inhibit this reflex. Alfaxalone causes similar

vasodilation to propofol yet preserves the compensatory abilities of the patient. It is because of this ability to compensate that alfaxalone is generally thought of to be more cardio-stable.

If bradycardia is present, cardiac output may be decreased and provoke the present hypotension. This is considered a state of decompensation because the body is not compensating for the decreased perfusion. First-line treatment for bradycardia with hypotension is IM or IV atropine or glycopyrrolate. These drugs are considered anticholinergic agents that decrease parasympathetic stimulation in the heart, resulting in a higher heart rate. When the heart rate returns to normal, cardiac output should improve, resulting in normotension.

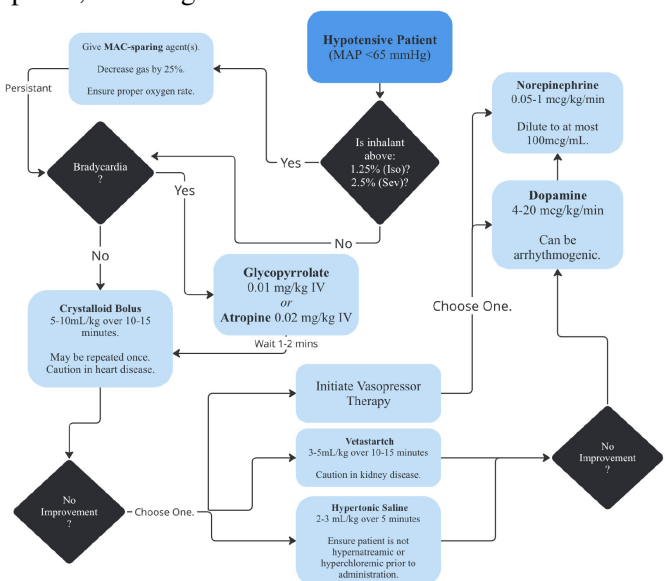

Figure 1. Hypotension flowchart for the average case in general practice anesthesia.

The typical first-line treatment for anesthetic hypotension is decreasing inhalant anesthetics. Inhalants, like isoflurane, cause widespread and profound vasodilation. Therefore, decreasing the percentage of inhalant anesthetics *can*, in turn, improve hypotension and therefore perfusion. However, it is important to remember that a reduction in inhalants can cause lightning in the anesthetic plane. This is when MAC-sparing agents are necessary, namely sedating opioids (fentanyl, morphine, hydromorphone), low-dose propofol, alfaxalone, dexmedetomidine, or ketamine. Generally, a positive response in blood pressure to decrease in MAC occurs within minutes depending on fresh gas flow.

In most cases, intraoperative hypotension is mediated by poor cardiac contractility (subsequent decreased cardiac output) and vasodilation. If decreasing MAC does not improve hemodynamics, the anesthetist must evaluate the cause of the present hypotension. If other perfusion parameters (i.e. heart rate, mucous membrane color, and pulse quality) are normal, intraoperative hypotension is generally mediated by vasodilation. One of the best ways to improve blood pressure secondary to vasodilation is volume replacement. This is usually achieved with crystalloid fluids. A bolus of 5-10 mL/kg IV over 15 minutes is the recommended *first* dose of fluids.[12] If blood pressure does not improve after the first bolus, the anesthetist must decide whether or not to continue volume replacement. This is typically dependent on the patients comorbidities, procedure, and drugs they've received. A second bolus can be given if vasodilation is suspected to be the primary cause of the present hypotension and the patient is not at risk of fluid overload. This also assumes the situation is not urgent enough to warrant pharmaceutical agents to improve hemodynamics. If crystalloids fail, colloids or drugs may be used to further correct vasodilation. The starting dose for most colloids is 5-10 mL/kg IV over 15-30 minutes.[13] If pressure is responsive to colloids, a CRI may be used of 1-2 mL/kg/hr in addition to crystalloid administration.[13]

If hypotension does not respond to crystalloids or colloids, vasoactive drugs may be used. These drugs have adrenergic activity to increase sympathetic tone. The most common include norepinephrine (NE), dopamine, and dobutamine. Each drug has various beta and alpha-adrenergic receptor selectivity and stimulation—meaning some cause vasoconstriction but also have positive inotropic/chronotropic effects. Dopamine is widely used as a preferred treatment for intraoperative hypotension. Dopamine causes norepinephrine release and acts directly and indirectly (via NE) on alpha and beta adrenergic receptors.[29] Dopamine CRI's should be started at 5-10 mcg/kg/MIN and titrated until effect. Some sources suggest rates up to 20 mcg/kg/min.[29] Dopamine must be used with continuous blood pressure monitoring via either direct or indirect measurements. A syringe pump is recommended to deliver the infusion as quick and accurate titrations can be achieved. Other non-catecholamine vasopressors such as phenylephrine and vasopressin also produce therapeutic vasoconstriction but are less commonly used in the general practice setting.[14] For a general practice setting, dopamine is the most practical and efficient option.

Vasodilation is not always the cause of intraoperative hypotension.

Several drugs (e.g. dexmedetomidine, acepromazine, inhalant) cause decreased cardiac contractility and/or bradycardia. Both of these lower cardiac output. Evaluating the present patient parameters will tell the anesthetist which factor of hemodynamics is causing the hypotension. Anticholinergics (i.e. glycopyrrolate) decrease vagal tone which increases cardiac output by bringing the heart rate up. Ephedrine, an alpha and beta adrenergic agonist, is a common medication to increase both SVR and CO. A bolus of ephedrine may be given to immediately boost hemodynamics if hypotension is suspected to be cardiac output mediated. If a positive response is seen, a CRI of ephedrine or other vasopressors may be utilized.

Other causes and treatments of hypotension exist. It is important for the anesthetist to reference several clinical observations with the quantitative data given by the monitor. Firstly, when the monitor shows a MAP <65 mmHg, the anesthetist should check the MM color and CRT. If both are normal, distal pulses should be palpated. Strong distal pulses generally indicate adequate perfusion. It is important to note that the force of a pulse that is felt is the difference between systolic and diastolic pressures, known as the pulse pressure. One may note a strong feeling pulse even with a low MAP as the systolic and diastolic may have a very large difference (e.g. 90/30). Pulse quality combined with quantitative clinical findings should be used to determine this. Previous theory suggested that the more distal a pulse is palpable, the higher the blood pressure; recent publications have suggested otherwise-- mostly due to pulse pressure variability. In cases of wide pulse pressure (i.e., systolic and diastolic pressures have a large difference), distal pulses may still be felt. In this case, a doppler may be used to assess pulse quality and manual distal blood pressures. Note that doppler readings only provide a systolic value which may be very helpful if the patient has a wide pulse pressure. If it is manually determined that the blood pressure is adequate, consider troubleshooting the equipment. Reposition the blood pressure cuff or try a different cuff.

It is important to note that preliminary data may indicate oscillometric (machine-cuff measured) blood pressure may be more accurate than manual doppler measures.[25] BP cuffs should be ~30-40% of the limbs circumference.[24] Additionally, the most accurate sites for measurement tend to be the antebrachium (mid-forelimb) or first few coccygeal vertebrae (base of the tail).[26] The extremity that is being used must be at heart-level and potentially clipped to improve accuracy if the fur/hair is thick.

Increased intrathoracic pressure can also cause hypotension via

decreased cardiac output. Several factors can raise intrathoracic pressure. One of them being excess ventilatory pressure. In a traditional rebreathing circuit, if the pressure release valve is closed, whether intentionally or unintentionally, more residual volume is kept in the lungs. If the pressure remains above 10 cmH_2O in the circuit for extended periods, the heart may have less physical area to contract and refill, resulting in a decreased cardiac preload and therefore output. This can also be seen with mechanical ventilation as normal physiology uses negative pressure to ventilate the lungs. When positive pressure ventilation is used, the intrathoracic pressure increases. Decreased preload or venous return to the heart can cause decreased cardiac output.[15] In patients with pregnancy or obesity, decreased preload may occur from caudal vena caval compression. When this patient is positioned in dorsal recumbency, pressure is put on the caudal vena cava which compresses the vessel, restricting the blood return from the body into the right atrium. To remedy this, left lateral recumbency may be advantageous; however, this may be impractical, especially in cases in which patients are required to be in dorsal recumbency (i.e., abdominal surgery). In those cases, other pressure support means should be provided to the patient.

Hypertension (HTN) is much less common than hypotension under general anesthesia. However, HTN can still cause complications. HTN is defined as a MAP >90 mmHg. A true hypertensive crisis is rare in anesthesia. The few unlikely but detrimental risks of anesthetic HTN are hemorrhage at the surgical site, retinal detachment, renal or GI ischemia, and cerebral ischemia or hemorrhage. One of the most common causes of anesthetic HTN is inadequate anesthetic depth. If the patient is too light, provide IV analgesics and sedatives to attempt to deepen the anesthetic plane. Although potent vasodilators, inhalants should not be increased in an attempt to vasodilate the patient. If the patient is adequately anesthetized, HTN may be tolerable. If a patient has primary cardiovascular disease or systemic cardiovascular disease, low-dose acepromazine 0.01-0.02 mg/kg IV may be advantageous in sedating and vasodilating the patient.[12, 16] Acepromazine decreases afterload on the heart, so it may also be useful in cases of CHF or other left-sided heart pathologies. Other injectable vasodilators may be advantageous, including esmolol or nitroprusside if HTN becomes intolerable or other signs or symptoms present (e.g., pulmonary edema).

Biochemical Imbalances

Chemicals in the body play vital roles in normal physiology. There

are several groups of these chemicals, including proteins, electrolytes, and others. Slight changes in concentrations of said groups can change the expected normal physiology of a patient. It is imperative for the anesthetist to understand biochemical imbalances and how they affect physiological processes.

Proteins are large molecules, also called macromolecules, that reside in the bloodstream. One function of proteins in the blood is to keep fluid from escaping extravascularly. Because proteins are so large, they are not easily transported by epithelial cells. This causes an osmotic gradient that, in normal physiology, is near or at equilibrium. Water follows tonicity; proteins are large molecules that generate oncotic pressure which in big part determines osmolarity. In turn, this loosely translates to "water follows proteins". The less protein in the blood, the less water in the blood, and vice versa. Hypoproteinemia (low blood protein content) is a potential cause of anesthetic hypotension via hypovolemia. While fluid resuscitation with crystalloids may temporarily hydrate the patient, the replacement of macromolecules is ultimately the treatment. The most common replacement proteins used in veterinary medicine are Hetastarch (hydroxyethyl starch) and albumin.

Other biochemical imbalances that may have several impacts on anesthesia are electrolyte imbalances. Electrolytes are charged atoms (ions) in the blood that play a crucial role in muscle, heart, brain, and hemodynamic function. The most clinically pertinent electrolytes typically are sodium (Na^+), potassium (K^+), and chloride (Cl^-) and calcium (Ca^{2+}). The most acutely deleterious imbalances are hyperkalemia, hypokalemia, hyponatremia, and hypernatremia. Hyperkalemia is an increase in K^+ blood content, resulting in decreased membrane potential in the cardiac myocytes. Essentially, this creates a delayed contraction of the atria and ventricles, which can eventually result in cardiac arrest. Hyperkalemia can be caused by urine retention (urinary obstruction), kidney disease, and trauma (crush injuries specifically). Hypokalemia is a low K^+ blood content resulting in lethargy, weakness, and irregular heart rhythms (eventually resulting in cardiac arrest). Causes of hypokalemia stem from fluid loss, such as vomiting/diarrhea and dilute urine (kidney disease, diuretics). Hypernatremia is an increased Na^+ blood content resulting in an osmotic gradient pulling fluid intravesically. Hemodynamics are not typically negatively affected by hypernatremia; however; the CNS is most affected by hypernatremia. Potential complications from hypernatremia include seizures and lethargy. The pathophysiology of this process is important to understand: increased blood sodium results in less fluid in the extravascular

spaces (i.e., cells). Some of the most affected cells are neurons. In turn, this can cause CNS abnormalities due to severe dehydration of neurons in the brain. Oppositely, low blood sodium (hyponatremia) can cause cerebral edema due to an osmotic gradient pulling fluid from the intravascular space into the neurons. Hyponatremia can also cause marked hypotension due to fluid shifting extravascularly.

Treatments of electrolyte imbalances are fairly intuitive: replace what is low and dilute or shift what is high. If low values are to be treated, careful replacement is indicated. For example, a patient with hypokalemia requires replacement potassium. Note that replacement potassium commonly is formulated as potassium chloride (KCl), which, when given too quickly, causes cardiac arrest. Use caution and dilution when administering KCl. However, high electrolyte values can be more complex to treat. Typically, hyperkalemia is treated with calcium salts, dilution (aggressive fluid therapy), and potentially insulin or albuterol (both agents shift K^+ into the intracellular space). Hypernatremia is usually treated with hypotonic fluids to dilute the Na^+ without adding more salt to the blood. Low electrolyte values are more commonly seen in the general practice setting, and mild cases can typically be replaced with a balanced maintenance fluid (e.g., Normosol-R/pH-Lyte; this fluid type contains electrolytes as salts in balanced ratios that allow for balanced replacement). Targeted replacement of electrolytes should be done via addition to maintenance fluids.

Respiratory and Ventilatory Abnormalities

Hypoxemia is low blood oxygen saturation (low SpO2). This can be a result of several pathophysiologies or mechanical errors. One of the most common causes of hypoxemia is ventilatory insufficiency. Ventilatory issues are generally caused by the patient receiving repository depressing drugs, unrecognized hypoventilation or apnea, and high circuit-pressures. If the pressure in a rebreathing circuit remains above 20 cmH2O (caused by closing the pop-off valve), the alveoli experience barotrauma. This causes an inflammatory response and can sometimes lead to ruptures in the alveolar sacs; this is a pneumothorax. Hypocapnia may also be noted with poor ventilation. To ensure the patient is exhaling waste gases such as CO2, it is important to recognize ventilatory abnormalities quickly. This is imperative to patient survival.

High ETCO2 is known as hypercapnia and is a result of inadequate ventilation. ETCO2 is an indirect measurement of PaCO2, the level of CO2 in the blood. Respiration is the act of our body using oxygen to make

energy and ventilation is the act of expelling our waste gases (CO_2). Hypercarbia (increased $PaCO_2$, secondary to poor ventilation) can cause a wide range of effects including respiratory acidosis, increased intracranial pressure, and a poor recovery. If hypercapnia is present for an extended period of time, mechanical ventilation is indicated. Hypercarbia can cause cerebral vasodilation, which can be detrimental in cases of head trauma. Cerebral vasodilation generally causes increased intracranial pressure (ICP). There are some cases in which hypercapnia may be advantageous to increase respiratory drive; this technique is known as permissive hypercapnia. Permissive hypercapnia is indicated for hypercapnia <65 mmHg and generally for no longer than 3-5 minutes. In normal physiology, the respiratory drive is stimulated by elevated CO_2 levels in the blood. Therefore, mild/moderate hypercapnia may aid in a patient's ventilatory effort and eventually decrease $ETCO_2$.

Ventilators are becoming more popular general practice and have been historically underutilized due to limits imposed by adequately trained personnel. Mechanical ventilators utilize positive pressure ventilation (PPV) in which the machine pushes air into the lungs of a patient, increasing intrathoracic pressure. Then, the machine releases this pressure which allows for exhalation of waste gases. The appropriate peak inspiratory pressure (PIP) for the average adult dog or cat is between 7-10 cmH_2O. The average tidal volume is calculated using 10-15 ml/kg. And the average respiratory rate should be around 8-12 breaths per minute. These parameters should be titrated against the end tidal CO_2 ($ETCO_2$) to keep it within 35-45mmHg depending on the patient's present illness(es). Respiratory rate and $ETCO_2$ are inversely proportional; increasing the rate will bring down the $ETCO_2$, this may be advantageous in cases of intracranial pathology. Increasing the PIP may be useful to recruit more of the alveoli and promote better gas exchange. Larger breaths (higher tidal volumes) may also be used to recruit more lung volume. Another parameter to facilitate control of ventilation includes positive end-tidal pressure (PEEP) which retains a slight amount of pressure in the lungs to prevent alveolar collapse. This can be done using 2-3 cmH_2O. However, increases in intrathoracic pressure from PPV (regardless of with or without PEEP) may cause slight tamponade of the heart and subsequently decreased cardiac output. If a mechanically ventilated patient is hypotensive, be sure to rule out excessive intrathoracic pressure. With newer technology, there is less and less room for human error. Some modern day veterinary ventilators auto-calculate tidal volume and adjust ventilatory settings based on the $ETCO_2$ and measured lung compliance. Technologies like these

have been lacking in veterinary medicine for years while our human counterparts have had these privileges. Its important practices begin to incorporate this updated technology and it makes for safer anesthesia.

If a mechanical ventilator is not available, intermittent PPV (iPPV) may be implemented. This technique uses manual ventilation to assist the patient in adequate ventilation. iPPV should be provided as a one-second breath with a PIP of 7-10 cmH2O as needed if the patient does not ventilate well, indicated by increased ETCO2.

A common ventilatory complication in small dogs and cats is hypercapnia and/or hypoxemia due to single-lung intubation where the ETT was inserted beyond the carina (bifurcation of trachea into main stem bronchi). This results in single bronchi intubation only providing oxygen and inhaled anesthetics to one lung. This presents several urgent and deadly problems, all resulting from only one functioning half of the normal available gas exchange area. This can quickly result in low oxygen saturation, acidosis, and an inadequate plane of anesthesia. Clinically, this will present with a low SpO2 value (<95%), low ETCO2, and potentially hyperventilation. Patients can eventually die, if left unrecognized, from hypoxia and acidosis. Acidosis results from a decreased ability to convert carbonic acid (H2CO3) in the blood into carbon dioxide in the lungs via normal respiration patterns (i.e., unable to exhale CO2). Treatment for this is fairly simple and has a high success rate if recognized and treated quickly. Carefully deflate the ETT cuff via the pilot balloon and slowly back out the ETT until ETCO2 values return to a normal range (35-45 mmHg) or until SpO2 returns to normal, which may take a moment. Then, re-inflate the cuff via the pilot balloon using the minimal occlusive pressure technique. This may be done by closing the pop-off valve and squeezing the rebreathing bag to bring the circuit pressure to 10-20 cmH2O. The anesthetist should listen for a leak while the pressure is elevated and inflate the cuff until no leak is heard. Note, it is always best to measure the length of ETT prior to intubation by measuring from the teeth to the thoracic inlet ensuring the tube does not extend past the thoracic inlet.

A more rare cause of intraoperative hypoxemia may be poor RBC or hemoglobin function. A low value in either is considered to be anemia. These two components are responsible for delivering oxygen and clearing carbon dioxide from the blood. If a patient had pathologies of their RBCs or hemoglobin, low blood oxygen levels may be observed. However, this is typically only noted in cases of moderate or severe anemia. Acute management of clinically significant/symptomatic anemia usually includes a blood transfusion, but other causes of poor hemoglobin function must

also be considered (e.g., methemoglobinemia secondary to various toxins). Simply put, the differential diagnosis of intraoperative hypoxemia are: 1) Low FiO2, 2) hypoventilation, 3) diffusion limitation, 4) ventilation-perfusion mismatch, 5) shunting.

Hypothermia

Temperature under anesthesia is quite variable and typically falls quickly if not appropriately prevented. The hypothalamus regulates body temperature. Many intrinsic and extrinsic mechanisms of the hypothalamus are suspended or blunted from most anesthetic agents. Simply put, this means patients are unable to control their body temperature while under general anesthesia to varying degrees. Hypothermia will occur in most anesthetized patients. Hypothermia generally causes decreased drug metabolization and elimination which can be detrimental for patients that have renal or hepatic dysfunction or other comorbidities that decrease drug metabolization and elimination. Because of this decreased metabolization and elimination of drugs, hypothermic patients tend to have an extended and dangerously slow recovery. Hypothermia also causes peripheral vasoconstriction in an attempt to shunt blood flow to the trunk of the body. Hypothermia may also cause sludging of blood flow and poor organ perfusion. It can also increase chances of infection and acid/base disturbances. In some cases, hypothermia can affect oxygen loading/ unloading from hemoglobin into tissues. Slightly low temperatures (≥ 99.0 °F) can be tolerated, but the anesthetist must always attempt to prevent and treat hypothermia. Methods of prevention include the use of a body warmer, IV fluid warmer, covering exposed body parts with towels, and covering paws. Feline and canine patients only sweat through their paws so an effective way to prevent heat loss is by putting socks on patients' paws. Another simple yet effective way to preserve temperature is to use ultrasound jelly to create contact with the ECG leads instead of alcohol (when alcohol evaporates, it takes heat with it). Methods of treatment of hypothermia are the same as prevention, just more aggressive. Specific techniques include increasing the IVF heater and body heater, applying warm objects to the axilla and groin, and decreasing peripheral vasodilation (i.e., decrease vasodilatory drugs, increase fluid rate, use vasopressors). In any anesthetic patient, temperature must be taken either every 5-10 minutes or continuously via an internal probe (nasal or esophageal).

Common Anesthetic Abnormalities; their Causes and Treatments				
Abnormality	**Value Definition**	**Causes**	**Treatments**	**Complications if Not Treated**
Hypotension	MAP <65 mmHg Note: 65mmHg is required for adequate brain and kidney perfusion.	Inhalants, propofol, acepromazine, sepsis, hypovolemia/ dehydration, shock, histamine release.	Check BP cuff location, feel for peripheral pulses, IV fluids, decrease inhalants, vasopressor therapy, consider other causes, consider positional causes.	Renal ischemia, anoxic brain injuries, poor recovery, hypothermia, shock, eventually death.
Hypertension	MAP >100 mmHg	Inadequate depth, surgical stimulation, primary CV disease, secondary CV disease.	Provide analgesia, increase depth, consider antihypertensive agents if profound and persistent.	Hemorrhage, pulmonary edema. Less acutely dangerous than hypotension.
Tachycardia	HR >25% resting Approx.(dogs): Small: >180 Medium: >130 Large: > 90 Cat: >180	Inadequate depth, surgical pain, hypotension and compensatory shock, ketamine, propofol.	Provide analgesia, consider increasing depth, check blood pressure (treat if low); if persistent, try beta-blocker or dexmedetomidine (increased ventricular filling).	Poor perfusion due to lack of ventricular filling, increased myocardial oxygen consumption.
Bradycardia	HR <25% resting Approx.(dogs): Small: <80 Medium: <60 Large: <50 Cat: <100	Acepromazine, some opioids, dexmedetomidine, profound anesthetic depth, AV blocks, late-stage shock.	Check blood pressure, try IV lidocaine before anticholinergic if from dexmedetomidine, lighten depth, use anticholinergic if hypotensive.	Poor perfusion due to lack of cardiac output. Bradycardia can be tolerable if blood pressure and other perfusion parameters are normal.
Hypothermia	Temp. <99 °F	General anesthesia, vasodilation, large surgically exposed site, volume loss, cool IV fluids.	Ensure proper heating methods (e.g., HotDog and warm IV fluids), place a towel for cover where possible, socks for paws, place warm objects in axillae, decrease anesthetic depth.	Prolonged recovery, hypotension, poor perfusion, potentially death if prolonged and not recognized.
Hyperthermia	Temp. >102.5 °F	Infection (fever), opioids (typically only in cats), underlying systemic disease.	IV fluids, uncover paws if possible, turn off body heater, monitor temperature q15 min, if worsening, discontinue inhalant anesthetics and switch to TIVA of propofol, or attempt to finish surgery ASAP.	Not acutely dangerous if <104.0. Hyperthermia associated with anesthesia is usually transient; more rare cases of malignant hyperthermia do occur but usually resolve when anesthesia is concluded.
Hypocapnia	$ETCO_2$ <35 mmHg	Hyperventilation, single-bronchus intubation, impending cardiac arrest, excessive anesthetic depth.	Confirm ETT placement, check SpO_2, lighten depth (if not hyperventilatory), consider manual ventilation.	Hypocapnia itself is not acutely dangerous but could lead to respiratory acidosis if unrecognized.

Hypercapnia	$ETCO_2$ >45 mmHg	Hypoventilation, increased metabolic function (hyperthyroidism), excessive anesthetic depth.	Lighten anesthetic depth, mechanical ventilation, 5-8mmH_2O PEEP, r/o underlying hyper-metabolic diseases.	Hypercapnia itself is not acutely dangerous if transient but could lead to poor cerebral perfusion, poor recovery, and respiratory alkalosis if unrecognized.
Hypoxemia	SpO_2 <95%	Mechanical error (ETT placement [single-bronchus intubation], oxygen tank empty, oxygen flowmeter turned off, SpO_2 probe malfunction), poor hemoglobin function, infection, pulmonary edema or bronchoconstriction.	Check ETT placement, check O_2 flow, reposition SpO_2 probe, check $ETCO_2$, auscultate breath sounds, and treat apparent abnormalities (e.g., Lasix for crackles with present hypertension). Consider manual ventilation if secondary to ventilatory abnormality.	Hypoxia, poor perfusion, shock, and eventually death.
Hypoventilation	RR <8 rpm	Excessive anesthetic depth, high breathing circuit pressure, increased intrathoracic pressure, GABA-agonists, and opioids.	Check breathing circuit (pop-valve open?), lighten anesthetic depth, discontinue GABA-agonists/opioids until resolved. If apnea/ extreme repository depression occurs from an opioid, reverse with butorphanol or naloxone; if it occurs from benzodiazepine, reverse with flumazenil.	Hypoxemia, hypoxia, shock, acidosis, eventually death.
Hyperventilation	RR >12 rpm	Improper ETT placement, inadequate depth, surgical pain, hydromorphone (panting), sympathetic stimulation from intubation.	Check ETT placement, increase anesthetic depth, provide analgesia, try IV lidocaine to help tolerate intubation.	Hypoxemia, hypoxia, shock, alkalosis, eventually, death.
Inadequate Depth	See Table 5	Surgical stimulation, pain, improper ETT placement, empty inhaler vaporizer, IVC infiltration (if using PIVA/TIVA), primary pulmonary disease.	Check ETT placement, check O_2 flow, check vaporizer level, check IVC placement. Try IV sedatives/analgesics.	Unexpected waking up, potential movement and subsequent surgical harm, high FAS (and potential trauma), quick but violent recovery.
Dysphoria	Thrashing, “swimming,” circling, and other inappropriate physical behaviors, excessive vocalization, aggression.	Inadequate pre-op sedation or intraop analgesia, stimulating pre-op/post-op area, loud noises, individual patient response to certain drugs, prolonged hypercapnia.	Bolus analgesics and sedatives (dexmed, opioids, acepromazine, propofol if urgent), dim lighting, quiet environment tightly wrapped blanket, human comfort (sitting with patient until calm).	Self-inflicted injury, poor recovery, pain, damage to surgical repairs, hypertension, tachycardia.

Chapter 3
Anesthetic Drug Lists

Please refer to drug monographs for more information on indications. Several less commonly used agents are not included in these reference tables due to a lack of clinical preference and newer agents becoming available.

All dosing, mechanisms, uses, and contraindications provided by Plumb's Veterinary Drug Handbook, 2024, unless otherwise denoted.

Opioids					
Drug Name (Brand Name)	**Canine Dose**	**Feline Dose**	**Duration of Action**	**Opioid Receptor Type**	**Notes**
Buprenorphine (Buprenex, Simbadol, Zorbium)	0.01-0.03 mg/kg IV, IM	0.01-0.03 mg/kg IV, IM See monograph for more dosing	5-8 hours	Partial Mu-Agonist	DEA Schedule III. Longest-acting opioid, mild-moderate analgesia. Minimal undesired effects (minimal sedation, vomiting, dysphoria)
Butorphanol (Torbugesic)	0.1-0.4 mg/kg IV, IM	0.1-0.5mg/kg IV, IM	1-2 hours	Mu-Antagonist, Delta/Kappa Agonist	DEA Schedule IV. Only provides mild analgesia. Reverses full-mu agonist effects. Potent sedative and anxiolytic.
Fentanyl (Sublimaze)	2-40 mcg/kg IV	2-40 mcg/kg IV	30-60 min	Full Mu-Agonist	DEA Schedule II. Short acting, potent analgesic and sedative. Especially useful in CRI's.
Hydromorphone (Dilaudid)	0.05-0.2 mg/kg IV, IM, SC	0.05-0.15 mg/kg IV, IM, SC	2-4 hours	Full Mu-Agonist	DEA Schedule II. Potent analgesic and sedative. High incidence of emesis and dysphoria (less so if given IV or in painful patients).
Methadone (Methadose)	0.1-0.6 mg/kg IV, IM, SC	0.05-0.5mg/kg IV, IM, SC	4-6 hours	Full Mu-Agonist	DEA Schedule II. Potent analgesic and sedative. Low side effect profile other than bradycardia.
Morphine (Duramorph)	0.5-1 mg/kg IV, IM, SC	0.1-0.25 mg/kg IV, IM, SC	2-3 hours	Full Mu-Agonist	DEA Schedule II. Fading preference due to short duration of action and high incidence of side effects. Causes clinically significant histamine release.

Tramadol (Ultram)	4-10 mg/kg PO	1-3 mg/kg PO	6-8 hours	Weak Mu-Agonist; Weak SNRI/Alpha-2 Agonist	DEA Schedule IV. Most clinicians use in multi-modal, at-home approach. Analgesic effects are weak without NSAIDs or gabapentin.
Ultra-Short Acting Opioids (Remifentanil, Alfentanil, Sufentanil)	0.5-1 mcg/kg/min CRI	0.5-1 mcg/kg/min CRI	3-10 min, depending on drug	Full Mu-Agonist	DEA Schedule II, used for PIVA and critically ill patient induction.

Sedatives					
Drug Name (Brand Name)	**Canine Dose**	**Feline Dose**	**Duration of Action**	**Class**	**Notes:**
Acepromazine (PromAce)	0.01-0.1mg/kg IV, IM, SC	0.01-0.1mg/kg IV, IM, SC	3-6 hours	Phenothiazine Tranquilizer	No analgesia, no reversal agent. Most clinicians prefer acepromazine as an adjunctive opioid anlagesic/sedative agent.
Dexmedetomidine* (DexDomitor, Sileo)	0.5-5 mcg/kg IV 2-10 mcg/kg IM	1-5 mcg/kg IV 8-20 mcg/kg IM	2-6 hours (dose-dependant)	Alpha-2 Adrenergic Receptor Agonist	High incidence of hypertension, reflex bradycardia, and eventual hypotension. Use with caution in geriatric or sick patients. Can be reversed. Now preferred by most over medetomidine (Domitor). Provides dose-dependent analgesia.
Diazepam (Valium)	0.1-0.5 mg/kg IV	0.1-0.3 mg/kg IV	1-4 hours	Benzodiazepine	DEA Schedule IV. Fallen out of favor in practice due to restricted administration routes (IV and rectally only) and high cost. Also used as induction adjunct.
Medetomidine/Vatinoxan (Zenalpha) Dose is medetomidine-based.	1 mg/m^2 IM (10-50 mcg/kg, dose decreases as weight increases)	Not labeled for use in cats.	30-45 mins	Alpha-2 Adrenergic Receptor Agonist/Antagonist	Combination medication; consists of medetomidine (Domitor) and vatinoxan, which is a selective peripheral antagonist. This reduces vasoconstrictive effects and decreases cardiovascular risks.
Midazolam (Versed)	0.1-0.5 mg/kg IV, IM, SC	0.1-0.5 mg/kg IV, IM, SC	2-4 hours	Benzodiazepine	DEA Schedule IV. Most prefer midazolam over diazepam as it has a lower incidence of respiratory depression, has a shorter duration of action, and can be given by most common routes. If used as a single agent in healthy and BAR animals, it can cause excitation (more so than diazepam). Also useful in preventing/treating seizures and status epilepticus. Midazolam is also indicated for adjunctive induction of anesthesia.

*There are other Alpha-2 Adrenergic Receptor Agonists (e.g., xylazine and medetomidine); however, dexmedetomidine is now regarded by many as the overall superior Alpha-2 Adrenergic Receptor Agonist for use in small animal anesthesia due to its more predictable effects compared to predecessors.

Induction Agents					
Drug Name (Brand Name)	**Canine Dose**	**Feline Dose**	**Duration of Action**	**Class**	**Notes:**
Alfaxalone (Alfaxan)	1-3 mg/kg IV, IM Avg: 2 mg/kg	1-5 mg/kg IV, IM Avg: 2 mg/kg	5-10 min	$GABA_A$-Agonist (General Anesthetic)	DEA Schedule IV. Provides no analgesia. Considered cardio-stable when given IM but may cause similar CV depression as propofol when given IV. Respiratory depression can occur.
Etomidate (Amidate)	0.5-2 mg/kg IV	0.5-2 mg/kg IV	3-5 min (dose dependant)	Parental GABA-Agonist (General Anesthetic)	Considered to be the most cardio-sstable induction agent. Agent of choice for critical patients. May cause vomiting and tremors.
Ketamine (Vetelar, Ketoflo)	2-5 mg/kg IV, IM	2-5 mg/kg IV, IM	15-60 min (dose dependant)	NMDA-Antagonist (Dissociative General Anesthetic)	DEA Schedule III. Causes catecholamine release (increases sympathetic activity). Avoid higher doses in geriatric or ill patients. Should never be used without proper premedication.
Propofol (Propoflo-28)	2-6 mg/kg IV	1-5 mg/kg IV	5-10 min	Parental GABA-agonist (Hypnotic General Anesthetic)	Give total dose over 60-90 seconds or until effective. Administration too quickly can cause respiratory depression. Causes vasodilation, which decreases cardiac output and can cause reflex tachycardia.
Tiletamine/Zolazepam (Telazol) (dosages are calculated based on 100 mg/mL formulation)	2-6 mg/kg* IV, IM	3-8 mg/kg IV, IM	30 min	Tiletamine: NMDA-Receptor Agonist (Dissociative General Anesthetic) Zolazepam: Benzodiazepine	DEA Schedule III. Newer combination drug. Very similar to ketamine/midazolam combination. *Labeled dose is much higher than typical dose used in practice.

Non-Steroidal Anti-inflammatory Drugs (NSAIDs)					
Drug Name (Brand Name)	**Canine Dose**	**Feline Dose**	**Duration of Action**	**Class**	**Notes:**
Carprofen (Rimadyl, Carprodyl)	4.4 mg/kg (2 mg/lb) q24hr PO, SC Can be divided into 2.2 mg/kg q12hr	Not recommended for feline use due to safer alternatives available.	12-24 hours (dose-dependant)	NSAID	Most common NSAID used in canine surgery for perioperative analgesia and inflammation. Avoid in cases of kidney disease, GI disease, and acute GI disturbances.
Meloxicam (Metacam)	0.1 mg/kg PO, IV, SC	0.1 mg/kg PO, IV, SC	24 hours	NSAID	Considered to be relatively safe for cats and provides mild analgesia. Avoid in cases of kidney disease, GI disease, and acute GI disturbances.
Robenacoxib (Onsior)	2 mg/kg SC	2 mg/kg SC 1-2 mg/kg PO	24 hours	NSAID	Mostly used in cats as carprofen/meloxicam are more commonly used for dogs. Avoid in cases of kidney disease, GI disease, and acute GI disturbances.

Note: Other common NSAIDs (firocoxib [Previcox], deracoxib [Deramaxx], grapiprant [Galliprant]) are not included in this table due to their administration being targeted for at-home use and lack of use in anesthesia. These NSAIDs do not have injectable formulations and are rarely used for in-hospital perioperative analgesia; most practitioners use these medications for at-home, non-surgical analgesia.

Local Anesthetics[18]					
Drug Name (Brand Name)	**Canine Dose**	**Feline Dose**	**Onset of Action**	**Duration of Action[2]**	**Notes:**
Bupivacaine 0.5% (Marcaine)	1-2 mg/kg (tissue infiltration) MAX DOSE: 3 mg/kg	1 mg/kg (tissue infiltration) MAX DOSE: 2 mg/kg	15-30 min	4-6 hours	Not for IV use. Most preferred local anesthetic by many due to long duration of action; however, also has intermediate onset of action.
Lidocaine 2% (Xylocaine)	4 mg/kg (tissue infiltration) MAX DOSE: 10 mg/kg	4 mg/kg (tissue infiltration) MAX DOSE: 5 mg/kg	5-15 min	1-2 hours	Do not use IV lidocaine in cats. Refer to monograph for IV lidocaine dosing and usage.
Mepivacaine (Carbocaine-V)	4 mg/kg (tissue infiltration) MAX DOSE: 10 mg/kg	4 mg/kg (tissue infiltration) MAX DOSE: 5 mg/kg	5-15 min	1.5-3 hours	Not for IV use. Inexpensive alternative to bupivacaine and has similar onset and duration of action.

Antimicrobial Agents					
Drug Name (Brand Name)	**Canine Dose**	**Feline Dose**	**Half-Life**	**Class**	**Notes:**
Ampicillin (Omnipen)	20 mg/kg IV over 3-5 min	20 mg/kg IV over 3-5 min	45-80 min	Aminopenicillin	Most common NSAID used in canine surgery for perioperative analgesia and inflammation. Avoid in cases of kidney disease, GI disease, and acute GI disturbances.
Ampicillin/Sulbactam (Unasyn)	22 mg/kg IV over 3-5 min	22 mg/kg IV over 3-5 min	45-80 min	Potentiated Aminopenicillin	Addition of sulbactam allows for better coverage against beta-lactam producing organisms. Considered to be injectable ClavaMox (in terms of clinical indications)
Cefazolin (Ancef)	20-22 mg/kg IV over 3-5 min	20-22 mg/kg IV over 3-5 min	2-3 hours	First-Generation Cephalosporin	Mostly indicated for orthopedic surgeries and lacerations. Provides broad spectrum coverage for gram-positive bacteria.
Clindamycin (Antirobe)	10 mg/kg IV over 10-60 min (dilute with saline)	10 mg/kg IV over 10-60 min (dilute with saline)	5 hours	Lincosamide Antibiotic	Indicated for lacerations, abscesses, and dental procedures. Provides broad spectrum coverage for gram-negative bacteria.
Penicillin-G	20,000-40,000 units/kg IM, SC	20,000-40,000 units/kg IM, SC	1 hour	Penicillin Antibiotic	Cannot be given IV, will cause adverse CNS effects. Limited preference due to newer techniques using IV prophylactic antibiotics.

Miscellaneous Supportive Medications Relevant to Anesthesia					
Drug Name (Brand Name)	**Canine Dose**	**Feline Dose**	**Duration of Action**	**Class**	**Indication/ Notes:**
Acetaminophen (Tylenol)	10-15 mg/kg PO or IV	DO NOT USE in cats!! Fatal at any dose.	6-8 hours	CNS COX inhibitor (no significant effect on inflammation)	Mild oral analgesic reserved for palliative care or severe pain requiring robust multimodal management.
Amantadine (Symmetrel)	3-5 mg/kg PO q12-24h	3-5 mg/kg PO q12-24h	12-24 hours	NMDA-receptor antagonist	Oral analgesic. Weak analgesia alone but useful in multimodal analgesia or for chronic pain.
Atropine	0.02-0.04 mg/kg IV, IM	0.02-0.04 mg/kg IV, IM	2-3 hours	Anticholinergic	Used in anesthesia for primary bradycardia. There are many contraindications and interactions. Please refer to the monograph before use.
Diphenhydramine (Benadryl)	0.5-2 mg/kg IV, IM, SC	0.5-2 mg/kg IV, IM, SC	8-12 hours	Antihistamine	Indicated for treatment or prevention of histamine related effects. Useful in mast cell tumor removals and other causes of histamine release (some opioids).

Famotidine (Pepcid)	1 mg/kg IV, SC	1 mg/kg IV, SC	4-8 hours	H2-antagonist	Used for gastric acid suppression and prevention of GI effects secondary to histamine release.
Glycopyrrolate (Robinul)	5-10 mcg/kg IV, IM, SC	5-10 mcg/kg IV, IM, SC	2-3 hours	Anticholinergic	Used in anesthesia for primary bradycardia. There are many contraindications and interactions. Please refer to the monograph before use.
Maropitant (Cerenia)	1 mg/kg IV, SC	1 mg/kg IV, SC	24 hours	Antiemetic/analgesic/antitussive	Primarily used in anesthesia to prevent perioperative vomiting. Also useful as an analgesic adjunct.
Metoclopramide (Reglan)	0.5 mg/kg IV, IM, SC, PO 1-2 mg/kg/day CRI	0.5 mg/kg IM, SC Less commonly used in cats	8 hours	Dopamine antagonist, Antiemetic/prokinetic	Used in anesthesia as an antiemetic and prokinetic in prevention of ileus or aspiration of gastric contents due to lack of laryngeal tone.
Ondansetron (Zofran)	0.5 mg/kg IV, PO Give IV dose over 3-5 min.	0.1-1.0 mg/kg IV, IM, SC, PO Give IV dose over 3-5 min.	8 hours	5HT3-receptor antagonist; Anti-nausea	In practice, most use ondansetron for its anti-nausea effects and is typically not used as an antiemetic alone. Most prefer co-administration of Cerenia (maropitant). Can reverse some serotonergic drugs. Many interactions possible.
Pantoprazole (Protonix)	0.7-1 mg/kg IV over 15 min	0.7-1 mg/kg IV over 15 min	12 hours	Proton Pump Inhibitor	Used for gastric acid suppression and prevention of perioperative aspiration.

ER Drugs			
Drug Name (Brand Name)	**Canine/Feline Dose**	**Action/ Class**	**Indications/ Notes:**
Atipamezole (Antisedan)	50-100 **mcg**/kg IV, IO, IM	Alpha-2 Adrenergic Antagonist	Indicated in reversal of Alpha-2 Adrenergic Agonists (specifically medetomidine and dexmedetomidine and amitraz toxicity).
Atropine	0.02-0.04 mg/kg IV, IM CPR: 0.04 mg/kg ONCE ASAP	Anticholinergic	Indicated for treatment of intolerable bradycardia. Useful in decreasing parasympathetic activity that is resulting in poor hemodynamic function.
Calcium Salts (-gluconate, -chloride)	5-15 mg/kg (elemental calcium) IV over 10-30 mins Check monograph for specific formulation dosing.	Electrolyte	Indicated in treatment or prevention of hypocalcemia and acute prevention of cardiac toxicity secondary to hyperkalemia. Use caution when calculating and administering due to various salts and concentrations.
Dexamethasone (Dexasone)	0.1-0.2 mg/kg IV, IM	Corticosteroid	Stabilizes mast cells, suppressing histamine synthesis and release. Helpful in cases of immune-mediated vasodilation (anaphylaxis shock), acute inflammation (asthma exacerbation). Also indicated in hypoadrenocorticism (Addison's) crisis.
Dextrose 50%	0.25-1.0 **mL**/kg IV diluted with 2 parts sterile saline, given slowly over 1-2 minutes, repeat until	Glucose-Elevating Agent	Can cause tissue necrosis if extravasation occurs. Administration through central venous access preferred. Bolus of dextrose 50% is typically followed by a 5% CRI

	desired BG		in isotonic fluids.
Doxapram (Dopram-V)	1.1 mg/kg q15-20 min until effect IV	CNS/Respiratory Stimulant	Indicated for repository depression and related CNS depression during or after anesthesia. Not commonly used in practice for anesthesia but a common agent used neonatal resuscitation post c-section.
Epinephrine (Adrenalin)	Anaphylaxis: 0.01 mg/kg IM CPR: 0.01 mg/kg IV, IO q3-5mins	Alpha/Beta Adrenergic Agonist	Vasoconstrictor, positive inotropic/chronotropic agent, bronchodilator. Useful in shock patients to reverse profound hypotension. Useful in CPR to encourage sympathetic activity. Double IV dose of intratracheal administration in CPR.
Flumazenil (Romazicon)	0.01-0.02 mg/kg IV	Benzodiazepine Reversal	Used to reverse adverse effects of benzodiazepines or other GABA-agonists either from veterinary administration or at-home accidental ingestion.
Furosemide (Salix, Lasix)	3-5 mg/kg IV, IM	Loop Diuretic	Indicated for the treatment of pulmonary edema/ CHF.
Glycopyrrolate	0.005-0.01 mg/kg IV	Anticholinergic	Indicated for treatment of intolerable bradycardia. Useful in decreasing parasympathetic activity that is resulting in poor hemodynamic function.
Lidocaine 2% (Xylocaine)	2 mg/kg IV q2mins Max dose: 8 mg/kg IV	Antiarrhythmic	Indicated in ventricular arrhythmias. Only for emergency use in cats; not for systemic non-emergent use (only in cats).
Naloxone (Narcan)	0.04 mg/kg IV, IO, IM, SC, PR	Opioid Antagonist	Indicated for emergency reversal of opioids due to respiratory depression, poor hemodynamic function secondary to opioid administration, and/or CPR in a patient that received opioids.
Sodium Bicarbonate	Prolonged CPR: 1-2 mEq/kg slow IV, IO	Alkalinizier	Useful in cases of acidosis (most commonly metabolic acidosis) and prolonged CPR with presumed acidosis. If used in CPR, ensure proper ventilation to avoid hypercapnia.
Yohimbine	0.1-0.25 mg/kg IV, IM	Alpha-2 Adrenergic Antagonist	Indicated in the emergent reversal of Alpha-2 Adrenergic Agonists (xylazine, amitraz, not dexmedetomidine). Atipamezole (Antisedan) is preferred by most to reverse Alpha-2 Agonists.

Vasopressors[17]					
Drug Name	**Canine/ Feline CRI Dose**	**Indication**	**Mechanism of Action**	**Adverse Effects**	**Contraindications**
Dopamine	5-20 mcg/kg/min	Severe shock and hypotension secondary to poor cardiac contractility and peripheral vasodilation.	Alpha and Beta Adrenergic Receptor Agonist	Nausea/vomiting, tachycardia, dyspnea, suppresses pituitary hormone release, arrhythmias.	Pheochromocytoma, ventricular fibrillation, uncorrected tachyarrhythmia.
Dobutamine	DOGS: 2-15 mcg/kg/min	Hypotension during general	Mixed Beta Adrenergic	Tachyarrhythmia, facial twitching,	Ventricular arrhythmias and atrial fibrillation.

(Dobutrex)	CATS: 1-5 mcg/kg/min	anesthesia.	Receptor Agonist	seizures.	
Norepinephrine (Levophed)	0.1-0.5 mcg/kg/min MAX: 1-2 mcg/kg/min	Profound shock and hypotension. Hypotension secondary to general anesthesia.	Alpha and Beta-1 Adrenergic Receptor Agonist	Weakness, pale mucous membranes, anxiety, dizziness, pulmonary edema and respiratory difficulty.	Hypovolemia (ensure proper fluid replacement prior to vasopressor therapy initiation). Preferably infused into a central catheter.
Vasopressin	0.03-0.3 unit/kg/HOUR	Adjunctive agent for shock and hypotension. Severe hypotension refractory to catecholamines.	Antidiuretic Hormone (ADH) which produces intense vasoconstriction and fluid retention.	Nausea, GI pain, hematuria, arrhythmias and increased bilirubin.	Chronic nephritis with nitrogen retention, vascular disease, seizure disorder, heart failure, cardiogenic shock and asthma.

Volatile (Inhalant) Anesthetics			
Drug Name	**Canine MAC**	**Feline MAC**	**Notes**
Desflurane	7-10.3%	9.8%	Primary benefit is quicker elimination time and subsequently quicker recovery. Not widely used due to special vaporizer requirements and associated cost. Not well tolerated in mask inductions due to airway irritant properties. Carries similar cardiorespiratory depressive risk as predecessors.
Isoflurane	1.3-1.4%	1.3-1.9%	Most common inhalant used in general practice due to ease of administration and low cost. Causes dose-dependent vasodilation resulting in hypotension.[7] Also causes myocardial depression. MAC-sparing agents may be advantageous in reducing isoflurane requirements and subsequent side effects.
Sevoflurane	2.1-2.4%	2.6-3.4%	Absorbed and eliminated more quickly than isoflurane (due to low solubility), resulting in quicker induction, titration, and recovery. More expensive than isoflurane. Appears to have similar cardiovascular depressive effects as isoflurane.

Analgesic/Sedative Constant Rate Infusion (CRI) Dosing				
Drug	**Rate**	**Loading Dose**	**Use**	**Notes**
Dexmedetomidine	0.5-5 mcg/kg/hr	0.25-1 mcg/kg IV	Analgesia, Sedation, MAC-sparing	Higher end of dosing range may be used for short-term sedation post-operatively.
Fentanyl	3-40 mcg/kg/hr	1-5 mcg/kg IV	Analgesia, MAC-sparing, PIVA	Most preferred opioid in CRIs due to short half-life and highly titratable analgesia. Respiratory depression occurs at high doses.

Hydromorphone	0.01-0.05 mg/kg/hr	0.05 mg/kg IV	Analgesia, MAC-sparing	Considered to be somewhat comparable to fentanyl CRI. May cause bradycardia at higher doses.
Ketamine	0.5-1.5 mg/kg/hr	0.5-1 mg/kg IV	Analgesia, MAC-sparing, PIVA	Notable dysphoria usually occurs at >0.8 mg/kg/hr. Lower post-op dosing or provide sedatives if using a higher dose.
Lidocaine	1-3 mg/kg/hr (up to 5.4 mg/kg/hr for antiarrhythmic)	0.5-1 mg/kg IV	Analgesia, Prokinetic, Cardio/Renal Protectant, MAC-sparing	Avoid in cats. Aids in systemic analgesia, produces a MAC-sparing effect, and is a cardiac and renal protectant.
Midazolam	0.1-0.3 mg/kg/hr	0.1-0.2 mg/kg IV	MAC-sparing, sedation, PIVA/ TIVA	Best used for short-term sedation/anesthesia
Morphine	0.1-0.2 mg/kg/hr	0.05-0.1 mg/kg IV	Analgesia, MAC-sparing	See Mini-Monograph on Morphine; less preferred over hydromorphone.
Propofol	0.1-0.5 mg/kg/MIN	2-6 mg/kg IV	PIVA/TIVA	Known to cause dose-/duration-dependant hypotension. Lower dose may also be used for status epilepticus.

Methadone and buprenorphine are not optimal for CRIs due to their long duration of action and difficulty of titration. Both of these drugs are commonly used as bolus analgesics every 6 hours.

Fluid Therapy		
Patient	**Fluid Type**	**Rate**
Healthy/awake for maintenance	Crystalloid	40-60 mL/kg/DAY (1-4 mL/kg/hr)
Sick and awake for replacement	Crystalloid	80-120 mL/kg/DAY (5-8 mL/kg/hr)
Anesthetized Patient		
Healthy for maintenance	Crystalloid	5-10 mL/kg/hr*
Cardiopulmonary disease	Crystalloid	2-5 mL/kg/hr
Diabetic	Crystalloid +/- 2.5% Dextrose if BG <150 mg/dL	5 mL/kg/hr
Hypotensive – mild	Crystalloid	5-10 mL/kg bolus
Hypotensive – moderate	Crystalloid	10-15 mL/kg bolus
Hypotensive – severe	See **Figure 1**.	

Boluses should be given over 5-15 minutes, depending on dose, and they should be accounted for when totaling the fluids administered. Hydration status should always be monitored when administering fluids, especially in a surgical context. *The author and contributors prefer 5mL/kg/hr for healthy dogs and 3mL/kg/hr for healthy cats although higher rates are still widely used.

Intravenous Fluids		
Name	**Indication**	**Notes**
Normosol-R, PlasmaLyte-A (same composition)	Fluid/Electrolyte replacement/maintenance	Most electrolytes out of any IVF solution. Balanced electrolytes. Isotonic.
Normal Saline (0.9% NaCl)	Fluid/Na^+ replacement	Normal saline (0.9%) is indicated for fluid replacement and hyponatremia or hypochloremia. Normal saline is isotonic. Hypotonic forms (0.45%) are useful in cases of hypernatremia and decreased extravascular volume. Hypertonic saline (>0.9%) is indicated for the treatment of shock, increased ICP, and hypovolemic conditions. Saline is an acidifying solution.
Hypotonic Saline (0.45% NaCl)	Dilution of Na^+ and water replacement	
Hypertonic Saline (1.5-7.5% NaCl)	Decreased intravascular volume, increased ICP, shock.	
Lactated Ringers (LRS)	Fluid replacement/maintenance	Lactated Ringers is an isotonic electrolyte solution indicated for volume replacement and alkalization. Avoid in synthetic liver dysfunction.
Dextrose Water (DW5)	Water replacement, Na^+ dilution, glucose supplementation.	Hypotonic solution used to dilute certain medication (e.g., norepinephrine) and to replace intravascular water in dehydrated patients or patients with hypernatremia.
Colloids (VetStarch, plasma products, Albumin)	Volume replacement	Last-line treatment for shock, hypotension, or severe volume loss. Blood transfusions are the first-line treatment for anemia.

Note: There are dozens of fluid solutions and types. This list is not comprehensive but outlines the most common preparations used in general practice.

Chapter 4
Mini-Monographs

These monographs are not intended for a comprehensive understanding of a drug; instead, these provide key ideas and important considerations for each drug. Please refer to other Veterinary Drug resources for more detailed monographs.

All data including dosing, mechanisms, uses, and contraindications provided by Plumb's Veterinary Drug Handbook, 2024, unless otherwise denoted.

Acepromazine (*PromAce*)

Class: Phenothiazine tranquilizer
Mechanism of Action: Dopamine antagonist and alpha-1 antagonist
Common Formulation and Controlled Status: Commercially available: 10 mg/mL injection and 10 mg and 25 mg tablets. Commonly diluted to 1 mg/mL in small animal practice. Non-controlled substance. Rx only.
Indications: Surgical premedication, procedural sedation, anxiolytic, antiemetic.
Contraindications: Moderate/advanced cardiovascular disease, organophosphate poisoning. Avoid in echocardiography and abdominal imaging (can cause CV depression and transient splenomegaly). Avoid in aggressive or very excited animals as acepromazine decreases inhibition. Acepromazine causes vasodilation via an alpha-1 antagonist.
Adverse Effects: Bradycardia, hypotension and sometimes reflex tachycardia, transient splenomegaly, transiently decreased RBC count, decreased platelet aggregation.
Onset and Duration of Action: Onset: 2-5 min (IV); 10-20 min (IM); 20-40 min (SC); 1-3 hours (PO). Duration is ~4-6 hours across all routes.
Specific Dosing:
Average Clinical Dose: 0.025 mg/kg IV, IM, SC

- 0.02-0.03 mg/kg IV, IM, SC with an opioid for surgical premedication or procedural sedation
- 0.01 mg/kg IV, IM, SC for top-up or sedation adjunct
- 0.005 mg/kg IV, IM, SC for conservative dose for at-risk patients
- 0.1-0.5 mg/kg PO for at-home sedation or for PVP as part of the "Chill Protocol" (PO dose much higher than injection due to poor

oral bioavailability)

Highlight Blurb:

Acepromazine is a phenothiazine tranquilizer that works in the CNS and is thought to decrease postsynaptic dopamine binding, resulting in CNS depression. Acepromazine also has several other tangential actions including alpha-1 adrenergic receptor antagonism which is thought to be the mechanism of vasodilation produced by acepromazine. Because of its action in the reticulating-activating system, acepromazine exhibits antiemetic and antispasmodic effects as well. Acepromazine has a long duration of action (up to 6 hours in some patients) and may take several minutes after IV administration to take effect. Acepromazine is widely used as a sedative for preoperative sedation but also has other uses—reducing afterload in the anesthetized patient and urethral relaxation in urinary obstructed cats. Common side effects include hypotension, reflex tachycardia, occasional paradoxical CNS stimulation, and excitation when used as a single agent. Because of its vasodilatory effects, acepromazine should be used with caution in patients where changes to hemodynamics can be detrimental. However, acepromzine's vasodilator effects may be fruitful in cases of increased left-ventricular preload (e.g., CHF) to decrease LV afterload and improve perfusion. Acepromazine provides no analgesia but potentiates opioid analgesic/sedative activity.

Acetaminophen *(Tylenol, Tylenol #2, 3, 4)*

Class*:* CNS COX-inhibitor; mild oral analgesic.
Mechanism of Action: Inhibits prostaglandin synthesis/binding specifically in the CNS; may also stimulate serotonergic and dopaminergic systems.
Common Formulation and Controlled Status: Commercially available: 350 and 500 mg tablets of plain acetophenone. Several opioid combinations exist. Most commonly combined with Codeine (Tylenol #2, 3, or 4, all with 300 mg acetaminophen with 15, 30, and 60 mg codeine respectively; Rx only, C-III). Non-controlled substance when alone. Available OTC when alone.
Indications: Adjunctive analgesic for severely painful patients requiring robust multimodal management. Also very useful in end of life care or cancer related pain. Typically recommended for acute use (<7 days) if utilized in non-hospice dogs.
Contraindications: FATAL AT ANY DOSE IN CATS; complete contraindication in cats. Known to cause hepatotoxicity in dogs with hepatic insufficiency or chronic use. It is recommended to monitor hepatic and renal values if using chronically.
Adverse Effects: methemoglobinemia, renal/hepatic toxicity, GI upset. Generally, well tolerated in dogs when used short-term at recommended doses.
Onset and Duration of Action: Onset: 10-15 min (IV); 1-2 hours (PO). Duration is ~6-8 hours across all routes. Bioavailability and clearance may be breed dependent, careful monitoring and reassessment is recommended.
Dosing:

- 10-15 mg/kg PO, IV every 8 hours. Some suggest q6 hour dosing may be more efficacious.
- 10-12 mg/kg PO every 12 hours is recommended for chronic use. Monitor liver and kidney values carefully.
- In combination with codeine:
    - First, calculate codeine at 1-2 mg/kg (not to exceed 2 mg/kg)
    - Then select tablet size based on 10-15 mg/kg of acetaminophen (not to exceed 15 mg/kg)
    - Example: 10kg dog → 10-20 mg codeine with 100-150 mg acetaminophen
        - ½ tablet of Tylenol #3 (codeine 30mg/ acetaminophen 300mg)

Highlight Blurb:

Acetaminophen is a last-line oral analgesic that should never be used in cats. Acetaminophen provides mild analgesia via COX-inhibition in the CNS. This reduces prostaglandin synthesis in the CNS producing central analgesia. Acetaminophen has no effect on inflammation and is safe to use with NSAIDs. Minimal safety and pharmacokinetic data exists for acetaminophen in dogs. Because of this, acetaminophen is reserved for extremely painful patients or those with a short life expectancy. Acetaminophen is commonly used in palliative care and hospice patients to improve comfort. Acetaminophen may also be advantageous in the at-home management of an extremely painful patient in cases of multimodal management. Commonly, acetaminophen is combined with codeine to provide increased analgesia. However, codeines pharmacokinetics is also poorly studied in dogs. It is known that codeine undergoes a high-first pass rate as with other oral opioids. The combination of acetaminophen and codeine is thought to provide moderate analgesia especially when used with a corticosteroid/NSAID and a gabapentinoid.

Alfaxalone (*Alfaxan*) C-IV

Class*:* Neuroactive Steroid, Injectable General Anesthetic
Mechanism of Action: $GABA_A$-receptor agonist which causes hyperpolarization of neurons.
Common Formulation and Controlled Status: Commercially available: 10 mg/mL injection. DEA Schedule IV controlled substance. Rx only.
Indications: Surgical premedication, general anesthesia induction and maintenance, procedural sedation, immobilization.
Contraindications: No major contraindications, well regarded as very safe even in critically ill patients. Can transition to other injectable general anesthetic but avoid simultaneous administration.
Adverse Effects: Respiratory depression or apnea at higher doses. When given IV, transient vasodilation and subsequent hypotension; IM administration has virtually no effect on hemodynamics. Excitation during induction or recovery may occur if insufficient premedication/sedation.
Onset and Duration of Action: Onset: 30-60 seconds (IV); 3-6 min (IM). Duration: 5-10 min (usually 15-20 min in cats). Duration may increase when used with other sedatives, with adequate analgesia, and higher alfaxalone dosing.
Dosing:

- 2-3 mg/kg IV for induction of general anesthesia (with premedication); infuse over 1-2 min
- 6-8 mg/kg/HOUR IV CRI for maintenance of anesthesia (TIVA)
- 1 mg/kg IM with an opioid and benzodiazepine for short but heavy sedation
- 2-3 mg/kg IM with sedatives for longer and heavy sedation
    - Aggressive cat sedation with minimal cardiovascular effects: (combine in same syringe for administration)
    - Alfaxalone 2-5 mg/kg IM (sedation depth is alfaxalone dose dependant)
    - Midazolam 0.2 mg/kg IM
    - Butorphanol 0.2 mg/kg IM

Highlight Blurb:

Alfalxone is a neuroactive steroid that produces sedation/general anesthesia by agonizing GABAA-receptors, resulting in hyperpolarization (due to an influx of Cl- rushing into the cell) of neurons in CNS. Alfaxalone is an interesting general anesthetic agent because it can be administered IM and therefore is commonly used at lower doses in sedation

cocktails and proves useful to immobilized patients. After IV administration, alfaxalone produces hypnosis for ~5-10 min in dogs and 2- to 3-fold more in cats (~15-30 min) without premedication or multimodal induction. Alfaxolone produces no analgesia. Much like other general anesthetics, alfaxalone may cause dose-dependent respiratory depression/ apnea if infused too quickly by IV. No major contraindications exist except for interactions with other GABA-agonists/repository depressants and significant hepatic dysfunction. Overall, alfaxalone is widely regarded as one of the most cardio-stable induction agents and is widely used for sedation cocktails in compromised animals.

Atropine

Class*:* Anticholinergic (antimuscarinic); vagolytic
Mechanism of Action: Inhibits acetylcholine binding (and cholinergics like toxins), blunts parasympathetic nervous system.
Common Formulation and Controlled Status: Commercially available: 0.54 mg/mL and 15 mg/mL injection. Non-controlled substance. Rx only.
Indications: To decrease vagal tone (to increase heart rate), to decrease mucosal/saliva secretions, to differentiate vagal-mediated bradycardia vs. other, in CPR to stimulate heart beats, and in organophosphate and blue-green algae poisoning as an antidote.
Contraindications: Dexmedetomidine-mediated bradycardia (if intolerable, much safer to reverse with atipamezole or try IV lidocaine), tachycardia may be intolerable for some patients with CV disease, therefore, use with caution in CV disease, avoid in HCM.
Adverse Effects: Dry mouth, vomiting, constipation, urine retention, stimulation/agitation, tachycardia, hyper- or hypotension.
Onset and Duration of Action: Onset: 3-4 min (IV); 10-20 min (IM). Duration: 30-60 min.
Dosing: Clinical effects are dose-dependent.

- 0.02-0.03 mg/kg IV for anesthesia-related bradycardia
- 0.01-0.02 mg/kg IM as a premedication to prevent bradycardia
- 0.04 mg/kg IV, IO, Intratracheal in CPR *once* if pulseless and non-shockable rhythm
- 0.02 mg/kg IV to determine if bradycardia is vagal-mediated

Highlight Blurb:

Atropine is an anticholinergic (specifically an antimuscarinic) that decreases acetylcholine binding. Acetylcholine (ACh) is the main neurotransmitter of the parasympathetic nervous system (PsNS). Atropine therefore decreases parasympathetic stimulation by inhibiting ACh-receptors. This yields several clinical effects; most commonly, atropine is used to treat vagal-mediated bradycardia. Atropine is contraindicated in patients for whom anticholinergic therapy (i.e., increased sympathetic tone) may be detrimental, such as narrow angle glaucoma, ureteral obstruction, and various heart diseases where tachycardia may be deleterious. Atropine is also used as an antidote for organophosphate poisoning and during CPR. Generally, atropine is used for the treatment of bradycardia. A potential contraindication is administration of atropine within 1 hour of alpha-2 adrenergic agonist (e.g., DexDomitor) administration. This is due to

significantly increased systemic vascular resistance (SVR) and therefore increased afterload. The administration of a positive chronotropic agent could put undue strain on the left ventricle and potentially cause extreme hypertension/ pressure overload. Atropine is generally more “aggressive” than glycopyrrolate as it works quicker, has a shorter duration of actions, and produces more tachycardia.

Bupivacaine (*Marcaine*)

Class*:* Amide Local Anesthetic
Mechanism of Action: Inhibits sodium ions on nerve cells, which causes hyperpolarization and decreased excitability.
Common Formulation and Controlled Status: Commercially available: 0.25%, 0.5%, and 0.75% injection. Non-controlled substance. Rx only.
Indications: To provide local, regional, or epidural analgesia.
Contraindications: Epidural analgesia is contraindicated in patients with shock or severe CNS disease.
Adverse Effects: Overall, well tolerated with minimal side effects. Known adverse effects include either CNS excitement or depression, hypotension, AV blocks, and decreased cardiac output. CV effects are rare and are more likely to occur at higher doses or in high-risk patients.
Onset and Duration of Action: Onset: 20-30 min (local infiltration). Duration: 3-5 hours.
Dosing: Most commonly used formulation in practice is 0.5%.

- 1-2 mg/kg for local infiltration
- 1 mg/kg with 0.1 mcg/kg dexmedetomidine for epidural or nerve block
- 1 mg/kg with 4 mcg/kg buprenorphine for epidural analgesia
- 3 mg/kg for peritoneal splash block

Highlight Blurb:

Bupivacaine is an amide local anesthetic that works by inhibiting sodium ion channels on the neuron cell membrane, which prevents depolarization. Bupivacaine is indicated for local analgesia via local tissue infiltration. Bupivacaine is also useful in epidurals, especially in combination with opioids. Unlike lidocaine, bupivacaine cannot be administered systemically; accidental systemic administration can cause severe CNS and cardiovascular effects, including ventricular arrhythmias and repository arrest. To avoid accidental systemic administration, always aspirate prior to injecting. There are no major contraindications to bupivacaine. Bupivacaine's onset of action is 20-40 min (compared to lidocaine, 3-8 min) with a duration of action of 3-5 hours (compared to lidocaine, 1-2 hours).

Buprenorphine (Buprenex, Simbadol, Zorbium) C-III

Class*:* Partial Mu-Agonist Opioid
Mechanism of Action: Partially agonzines the MOR while antagonizing the KOR/DOR.
Common Formulation and Controlled Status: Commercially available: 0.3 mg/mL injection (*Buprenex*, generic); 1.8 mg/mL injection (*Simbadol*); 20 mg/mL transdermal solution (*Zorbium*). DEA Schedule C-III controlled substance. Rx only.
Indications: Surgical premedication and moderate analgesia.
Contraindications: Sensitivity to opioids, poorly controlled metabolic or endocrine disease. Use caution in cases of hepatic dysfunction. Not recommended for emergency or rescue analgesia due to long onset of action.
Adverse Effects: Overall, adverse effects are minimal as compared to other opioids: euphoria/dysphoria, sedation, vomiting, diarrhea, constipation, drooling, decreased appetite (noted with high-dose SC administration in dogs), panting, and vocalization.
Onset and Duration of Action: Onset: 15-30 min (IV); 30-45 min (IM). Duration: 6 hours (standard IM or IV injection), 24 hours (Simbadol SC use in cats), 4 days (Zorbium transdermal use in cats).
Dosing: There are several formulations and specific dosing with each. Use caution with calculating and administering buprenorphine.
Dogs:

- Buprenex (0.3 mg/mL) 0.01-0.03 mg/kg IV or IM (duration 6 hours)
- Simbadol (1.8 mg/mL) 0.01-0.03 mg/kg IV or IM (best used in big dogs, duration 6 hours)
- Oral Transmucousal (OTM) administration for at-home analgesia: 0.05 mg/kg OTM (duration ~6-8 hours)

Cats:

- Buprenex (0.3 mg/mL) 0.01-0.03 mg/kg IV or IM (duration 6 hours)
- Simbadol (1.8 mg/mL) 0.24 mg/kg SC (cats only, duration 24 hours)
- Zorbium (20 mg/mL) ~2.7-6.7 mg/kg T/D (use weight ranges supplied on box, duration 72-96 hours)
- Oral transmucosal (OTM) administration for at-home analgesia: 0.05 mg/kg OTM (duration ~6 hours)

Highlight Blurb:

Buprenorphine is a partial-MOR (mu-opioid receptor) agonist and KOR (kappa-opioid receptor)/DOR (delta-opioid receptor) antagonist.

Buprenorphine displays a high potency and high affinity for the MOR, much more so than full-MOR agonists (e.g., morphine); thus, less drug is required to produce similar effects. Buprenorphine produces moderate analgesia that is thought *not* to be dose-dependent because of a phenomenon called the "ceiling effect"; increasing dose will not increase effects but will increase the duration of action. Buprenorphine's ceiling effect allows for several long-acting vehicles. Simbadol (24-hour subcutaneous buprenorphine for cats) uses this ceiling effect to produce 24 hours of analgesia. Other than analgesia, buprenorphine effects are very mild, causing minimal GI effects and little to no sedation but good anxiolysis. The average duration of action of standard parenteral administration is ~6 hours (at 0.02 mg/kg or 20 mcg/kg). Buprenorphine is not recommended for emergency analgesia as the onset of action can be anywhere from 25-60 minutes due to its partial-agonism property. Buprenorphine typically displaces other full-MOR agonists such as hydromorphone due to buprenorphine's high affinity for the MOR. Buprenorphine is well absorbed after IM administration but is not recommended for SC administration (besides Simbadol) due to unpredictable absorption. Buccal or oral-transmucosal (OTM) buprenorphine is also widely used in cats, less so in dogs; the dose is generally higher than parenteral dose due to lower bioavailability.

Butorphanol (*Torbugesic*) C-IV

Class: Agonist/Antagonist Opioid
Mechanism of Action: Antagonizes the MOR while agonizing KOR.
Common Formulation and Controlled Status: Commercially available: 2 mg/mL and 10 mg/mL injection; 1, 5, and 10 mg tablets. DEA Schedule C-IV controlled substance. Rx only.
Indications: Sedation for minor procedures, anxiolytic, antitussive, reversal of full-mu agonist opioids (e.g., morphine) in urgent but not emergent cases.
Contraindications: Sensitivity to opioids, poorly controlled metabolic or endocrine disease, use caution in cases of hepatic dysfunction. Not recommended for patients with copious mucus production due to butorphanol's antitussive effects (potential for airway obstruction). Contraindicated in painful patients or surgical patients as butorphanol provides very poor analgesia and reduces efficacy of other opioids for up to 8 hours.2 Use naloxone to reverse full-mu opioids instead of butorphanol in true emergencies.
Adverse Effects: Overall, very well tolerated and safe drug. Most notable adverse effects, although uncommon, are sedation, ataxia, disorientation, excitation, mydriasis, hypersalivation, anorexia, vomiting, diarrhea. Occasionally bradycardia and subsequent hypotension may be seen but generally very slight; if significant, treat with an anticholinergic. GI effects are rare.
Onset and Duration of Action: Onset: 1-2 min (IV); 5-15 min (IM). Duration: 2-4 hours. Oral administration is very rarely used in practice today.
Dosing: Oral administration is very rarely used in practice today.

- 0.1-0.5 mg/kg IV, IM, SC for general dosing
- 0.2 mg/kg IV, IM, SC with sedatives
- 0.3 mg/kg IV for anxiolysis
- 0.1 mg/kg IV for full-mu agonist reversal
- 0.1 mg/kg IV or 0.2 mg/kg IM as an antitussive or in cases respiratory distress

Highlight Blurb:

Butorphanol is a MOR (mu-opioid receptor) antagonist and KOR (kappa-opioid receptor)/SR (sigma-receptor) agonist. Butorphanol provides mild analgesia with decent sedation (dose-dependent) via KOR/SR agonism. Butorphanol is also indicated for large-bowel diarrhea and as an

antitussive. Butorphnaol is helpful in cases of respiratory distress to relax lower airways and calm the patient. Because of MOR antagonism, butorphanol reverses effects of full-MOR agonists such as fentanyl. Butorphanol may be used as a reversal agent for deleterious effects of full-MOR agonists, such as repository depression, while still providing some analgesia. Some clinicians prefer butorphanol over naloxone for full-MOR agonist reversal; however, butorphanol should never be substituted for naloxone in an emergency. Butorphanol has a quick onset of action (60-90 seconds IV, 5-15 minutes IM, 30-60 minutes SC) and decent duration of sedation (~2-4 hours) but only provides analgesia for ~40 minutes. Butorphanol is best used as a sedative or sedative adjunct and not for analgesia in a surgical setting.

Carprofen (*Rimadyl*)

Class*:* Non-Steroidal Anti-Inflammatory Drug (NSAID)
Mechanism of Action: Selective COX-2 inhibition, which inhibits prostaglandin synthesis. Prostaglandins play a crucial role in the inflammatory cascade by recruiting immune cells and causing increased permeability of capillaries. Prostaglandins also cause chemical insults to peripheral nerves which causes pain.
Common Formulation and Controlled Status: Commercially available: 25, 75, and 100 mg tablets; 50 mg/mL injection. Non-controlled substance. Rx only.
Indications: Analgesia associated with osteoarthritis and surgery in dogs.
Contraindications: Feline patients (short-term use in other countries has been reported to be safe), history of GI ulceration, acute GI distress, chronic inflammatory syndromes (e.g., IBD), renal or hepatic impairment, bleeding or clotting disorders, and concurrent administration with corticosteroids.
Adverse Effects: Well-tolerated in healthy patients when administered appropriately. Most common side effects include GI upset (vomiting, diarrhea, anorexia), renal and/or hepatic damage, and GI ulceration. Must give the oral formulation with a meal to decrease risk of GI ulceration. Parenteral carprofen has a lower incidence of GI ulceration/upset due to bypassing the GI tract.
Onset and Duration of Action: Onset: 1-2 hours (SC). Duration: 12-24 hours (dose-dependent).
Dosing:

- 4.4 mg/kg SC at induction for surgery or during sedation for painful procedures
    - Equivalent to 2 mg/lb (POUNDs, not kilograms)
    - Analgesia persists for 24 hours
    - Note: the author and contributors prefer 2.2 mg/kg SC post-op due to the prevalence of intraoperative hypotension and risk of AKI. Analgesia of this dose persists for 12 hours.
- 2.2 mg/kg PO BID for at-home use (tends to be better tolerated than 24-hour oral dosing)

Highlight Blurb:

Carprofen is an NSAID and produces analgesic, antipyretic, and anti-inflammatory effects. Cyclooxygenase (COX) receptors are responsible for prostaglandin synthesis via cell signaling. Carprofen is a

weak selective COX-2 inhibitor, as it inhibits COX-1 receptors at a lesser rate. Prostaglandins recruit inflammatory cells, producing pain, inflammation, and fever. COX-1 receptor inhibitors are typically associated with a higher incidence of GI ulceration and renal and hepatic impairments. Because of this, carprofen is widely regarded as one of the safer NSAIDs for dogs. Safety in cats is still somewhat ambiguous, and it is recommended to use safer NSAID alternatives (robenacoxib and meloxicam). Carprofen use should be avoided in patients with acute or chronic hepatic, renal, or GI disease/impairment. Concurrent use of other NSAIDs and corticosteroids is cautioned against due to higher incidence of GI ulceration and immunosuppression. Carprofen can be given SID at 4.4 mg/kg producing 24-hour effects or split into BID doses of 2.2 mg/kg for 12-hour effects.

Dexmedetomidine (DexDomitor, Sileo)

Class: Alpha$_2$ Adrenergic Receptor Agonist
Mechanism of Action: Agonizes alpha$_2$ receptors (auto-receptor on presynaptic neuron in the CNS/PNS) in CNS, PNS, and vasculature, which decreases norepinephrine release to produce varying levels of sedation, analgesia, anxiolysis, and vasoconstriction.
Common Formulation and Controlled Status: Commercially available: 0.5 mg/mL (500 mcg/mL) and 0.1 mg/mL (100 mcg/mL) injection; 0.09 mg/mL (90 mcg/mL) oral-transmucosal gel (Sileo). Non-controlled substance. Rx only.
Indications: Dexmedetomidine injection is indicated for in-hospital sedation, surgical premedication, analgesia, and anxiolysis, as well as to improve ventricular filling time in cases of sinus tachycardia. Dexmedetomidine oral-transmucosal gel is indicated for at-home sedation for noise aversion; anecdotally, some have reported using the gel for at-home rescue analgesia (unclear whether it provides true analgesia or calming). The gel may also be used 30 minutes prior to veterinary visits as part of a "Fear-Free" protocol.
Contraindications: Some forms of CV disease, acute respiratory syndromes, shock, liver/kidney disease, extreme stress. CV syndromes in which dexmedetomidine may be detrimental include electrical syndromes or abnormalities, HCM, DCM, and CHF. Use caution (and lower doses) in geriatric patients.
Adverse Effects: At low doses (much lower than FDA-approved labeled dosing), dexmedetomidine has minimal clinically significant adverse effects. Most common adverse effects include vasoconstriction, subsequent transient hypertension, reflex bradycardia, AV blocks, SVT, PVCs, hypoventilation, hyperglycemia, and vomiting (very common in cats; butorphanol, maropitant, and ondansetron have all been shown to reduce emesis in cats receiving dexmedetomidine). At high doses (including some FDA-approved labeled dosing), adverse effects may include apnea, prolonged sedation, hypotension (after transient hypertension), shock, pulmonary edema, and death from circulatory failure.
Onset and Duration of Action: Onset: 1-2 min (IV), 5-10 min (IM), 15-30 min (OTM). Duration (dogs): 1-4 hours (dose-dependent), (cats): 2-6 hours (dose-dependent).
Dosing:

- 1-5 mcg/kg IM or IV for surgical premedication with an opioid

- 1-3 mcg/kg IV for rescue sedation or mild analgesia
    - Note: the author and contributors prefer only giving 1 mcg/kg at a time. This dose is diluted and given over 5-10 mins.
- 3-10 mcg/kg IM or IV with other sedatives for moderate to deep sedation
- 0.5-3 mcg/kg/hr IV CRI for analgesia, PIVA, MAC-sparing, and ICU/ recovery sedation
- 3-5 mcg/kg using Sileo gel (each dosing dot delivers ~22.5 mcg) [or use labeled dosing chart]
- 1 mcg/mL (NOT mcg/kg) for epidural administration-- calculate out the local anesthetic dose and add enough dexmedetomidine to create 1 mcg/mL of the local anesthetic solution.
    - Example: a 10kg dog would need 20mg of bupivacaine (@ 2 mg/kg) which is 4.0mL of the 0.5% bupivacaine. Then, by adding 4 mcg (0.04mL of 0.1 mg/mL dexmedetomidine), the epidural solution now has a concentration of dexmedetomidine of 1 mcg/mL.

Highlight Blurb:

Dexmedetomidine is an alpha-2 adrenergic receptor agonist (also called "alpha-2"). Alpha-2s produce dose-dependent analgesia, sedation, and anxiolysis via inhibited release of norepinephrine in the CNS and PNS. Alpha-2_A receptors are mostly found in the CNS and PNS, allowing sedation and analgesia. Alpha-2_B receptors are found in smooth muscle, especially blood vessels. Dexmedetomidine causes peripheral vasoconstriction via agonism of alpha-2_B receptors in smooth muscle; this agonism is transient as effects of alpha-2_A agonism outlast alpha-2_B agonism. Due to initial peripheral vasoconstriction, dexmedetomidine increases systemic vascular resistance (SVR), which can dramatically increase left-ventricular (LV) afterload. Consequent biphasic hemodynamic changes occur; hypertension is present for about 30-60 minutes with initial dexmedetomidine administration followed by normotention or hypotension. Due to the baroreflex, dose-dependent reflex bradycardia may be present. After the initial 30-60 minutes of hypertension/bradycardia, blood pressure typically decreases, and patients may become hypotensive without reflex tachycardia. Avoid dexmedetomidine in patients where peripheral vasoconstriction, increased SVR, and increased LV afterload may be detrimental (most cases of CV disease). Additionally, dexmedetomidine relaxes cardiac myocytes, which decreases inotropy (force of contraction) significantly; avoid in patients where this effect can be deleterious. Intravenous lidocaine 2% may also be helpful in minimizing hemodynamic

changes. While the mechanism is still unknown, lidocaine at 2 mg/kg IV upon or following dexmedetomidine administration can dramatically improve bradycardia and hypertension, and it may increase cardiac contraction. Dexmedetomidine can be revered with atipamezole; this can be done routinely to speed recovery or in an emergency due to significant cardiovascular depression. Dexmedetomidine is commonly used in both dogs and cats as a sedative, analgesic, and preanesthetic. Labeled doses are much higher (up to 40 mcg/kg) than typically used in practice (1-5 mcg/kg). Dexmedetomidine can be given IV, IM, or as a CRI to aid in analgesia and sedation. Oral-transmucosal dexmedetomidine gel (Sileo) is now available for use in dogs only for acute noise aversion but has been used off-label for Fear-Free protocols and analgesia. In cats, dexmedetomidine causes nausea and vomiting due to a high concentration of alpha-2 receptors in the cat's chemoreceptor trigger zone (CRTZ). Dexmedetomidine's half-life is around 1 hour, producing a dose-dependent duration of action of ~1 hour per 1-3 mcg/kg (anecdotal based on the author's clinical experience).

Diazepam (*Valium*) C-IV

Class: Benzodiazepine
Mechanism of Action: $GABA_A$-receptor agonist that allows Cl^- to rush into the neuron, rendering a state of hyperpolarization. This relaxes various parts of the brain and brainstem to various degrees.
Common Formulation and Controlled Status: Commercially available: 5 mg/mL injection; 2, 5, and 10 mg oral tablets. There are several formulations of oral/rectal solutions, but these are not commonly used. DEA Schedule C-IV controlled substance. Rx only.
Indications: Anxiolytic, anticonvulsant, muscle relaxant, appetite stimulant, anesthetic premedication, and induction agent.
Contraindications: Oral administration in cats, hepatic disease, aggression (benzodiazepines can decrease inhibition of aggressive behaviors and therefore exacerbate aggression; also pair with another sedative class to ensure proper sedation in aggressive animals). IM administration is avoided due to erratic absorption and injection site pain upon administration.
Adverse Effects: Sedation, ataxia, increased appetite, aggression and agitation, rapid IV administration known to cause hypotension. Respiratory depression may occur. Administration alone may cause excitation; consider administering an opioid or $alpha_2$-agonist to decrease excitation.
Onset and Duration of Action: Onset: 1-2 min (IV). Duration: 4-10 hours (up to 12 in cats).
Dosing:

- 0.2 mg/kg IV for surgical premedication with an opioid
- 0.2 mg/kg IV with an injectable general anesthetic for anesthetic induction
- 0.1 mg/kg IV for procedural sedation with other sedatives
- 0.1 mg/kg IV as an anxiolytic and to stimulate appetite in hospitalized patients
- 0.3-0.5 mg/kg IV for status epilepticus

Highlight Blurb:

Diazepam is a benzodiazepine and therefore a $GABA_A$-receptor agonist that promotes relaxation, sedation, and anxiolysis. GABA receptors are in high concentration in the medulla, which can produce dose-dependent respiratory depression and/or apnea. Diazepam is not easily water-soluble and readily soluble in a lipid solution; diazepam injection is made with a propylene glycol solution. Due to the viscous nature of this solution, IM administration is not advised and may cause injection-site

pain. Diazepam should be used with caution in hepatic or renal impairment and extreme caution with comatose patients and patients that received other respiratory depressants. Always administer diazepam with other sedating agents in aggressive patients. Administration of IV diazepam without other sedating agents may cause excitation. At normal doses, diazepam is considered to be cardio-stable, as it produces little hemodynamic changes in healthy patients. Diazepam's duration of action is 4-12 hours (highly variable).

Etomidate (*Amidate*)

Class: GABA-Agonist, Injectable General Anesthetic
Mechanism of Action: GABA-receptor agonist that allows Cl^- to rush into the neuron, rendering a state of hyperpolarization to a higher degree than benzodiazepines.
Common Formulation and Controlled Status: Commercially available: 2 mg/mL injection. Non-controlled substance. Rx only.
Indications: Induction of general anesthesia in high-risk or critically ill patients.
Contraindications: Overall, very safe. Use lower-doses and caution in patients with hepatic disease. Note that etomidate is reserved for induction of high-risk or critically ill patients; use should generally be avoided in healthy patients due to lack of data on effects of etomidate and more effective options being available for non-critical patients.
Adverse Effects: Very well tolerated, and adverse effects are usually insignificant if proper premedication is used. Common adverse effects include vomiting, phlebitis, pain at injection site (some dilute etomidate to reduce pain and risk of phlebitis), and adrenocortical suppression. In critically ill patients, supplemental corticosteroids may be advantageous to prevent shock. Some practitioners report prophylactically giving corticosteroids to all patients receiving etomidate.
Onset and Duration of Action: Onset: 30-60 seconds (IV). Duration: 3-5 min.
Dosing:

- 1-2 mg/kg IV titrated until effect for induction of general anesthesia
- 0.5 mg/kg IV titrated until effect for induction of general anesthesia when using midazolam or ketamine as a co-induction agent

Highlight Blurb:

Etomidate is an injectable general anesthetic, specifically a GABA-agonist. Etomidate is only indicated for induction of general anesthesia and is typically reserved for patients with profound pre-existing cardiac disease or critically ill patients. Generally, etomidate is considered the most cardio-stable induction medication in veterinary medicine, but some suggest alfaxalone may be a better option due to more reliable data of use in veterinary medicine. Etomidate's use in general practice is minimal. Etomidate provides no analgesia and has a similar onset and duration of action as propofol (3-5 min). Etomidate inhibits cortisol production and requires supplementation of corticosteroids in patients with acute or

chronic adrenocortical insufficiency (e.g., shock or hypoadrenocorticism). There are no complete contraindications or adverse effects reported with use of etomidate. Etomidate should be worked into a protocol in place of other general anesthesia such as propofol.

Fentanyl (*Sublimaze*) C-II

Class*:* Full-mu-agonist opioid
Mechanism of Action: Agonizes mu-opioid receptor (MOR)
Common Formulation and Controlled Status: Commercially available: 0.05 mg/mL (50 mcg/mL) injection. DEA Schedule II controlled substance. Rx only.
Indications: Surgical analgesia (especially in orthopedic procedures), analgesia for painful but short procedures, partial intravenous anesthesia (PIVA), general anesthesia induction of ill patients, emergency or rescue analgesia.
Contraindications: Overall, very safe when used correctly. Use with caution in patients with CNS or respiratory depression. Use caution when administering with other CNS, repository, or cardiovascular depressants. Use with caution in geriatric, ill, or debilitated patients; use sparingly in cases of GI obstruction or renal/hepatic impairment. Fentanyl can be fatal if a patient is overdosed or if personnel are accidentally exposed to large quantities. Be sure to have both human and veterinary naloxone readily available.
Adverse Effects: Minimal side effects when used correctly. CNS (sedation), respiratory (hypoventilation, apnea), and cardiovascular (bradycardia and hypotension) depression are possible. Anticholinergics have been shown to improve cardiac output in anesthetized dogs receiving fentanyl.
Onset and Duration of Action: Onset: 30-60 seconds (IV). Duration: 20-40 min.
Dosing: A,ll IV doses should be titrated until effect as effects are variable.

- 2-10 mcg/kg IV for general analgesia, generally, titrate until effect.
    - This dose can be given IM but IV administration is preferred because of its titratable analgesia and sedation.
- 5-10 mcg/kg/hr IV CRI for analgesia
- 10-40mcg/kg/hr IV CRI for PIVA

Highlight Blurb:

Fentanyl is a potent full-MOR agonist that produces dose-dependent analgesia, sedation/hypnosis, and respiratory depression. Fentanyl is widely used in veterinary medicine and is indicated for control of acute pain related to surgery or trauma and as an anesthesia adjunct. Fentanyl is the bolus or emergency analgesic of choice due to its fast onset and duration of action, allowing other longer-acting opioids to be administered once

stabilized. Fentanyl (and its ultra-potent derivatives remifentanil, alfentanil, sufentanil) is best utilized as a CRI, as it has a very short duration of action (20-30 minutes); it produces dose-dependant sedation and hypnosis, which is why it can be utilized as an induction agent (typically only in critically ill patients) and a maintenance adjunct. Fentanyl has a wide dose range (1-10 mcg/kg) and should be titrated until effect. Because of this, IM administration is not recommended, although IM fentanyl still produces clinical effects. Fentanyl commonly causes respiratory depression, and mechanical ventilation may be necessary at high doses and if used in conjunction with other respiratory depressants. Fentanyl effects (analgesia, sedation, repository depression) can be reversed with naloxone or butorphanol (not recommended for emergency reversal). It is important to have human-labeled naloxone nasal sprays (Narcan) in-hospital in case of accidental personal exposure. There are no complete contraindications. Fentanyl is very cardio-stable and does not typically affect hemodynamics (incidences of bradycardia have been reported).

Glycopyrrolate (*Robinul*)

Class*:* Anticholinergic (antimuscarinic)
Mechanism of Action: Inhibits acetylcholine binding at the parasympathetic neuroeffector sites, which decreases parasympathetic activity. Glycopyrrolate does not penetrate the CNS, unlike atropine.
Common Formulation and Controlled Status: Commercially available: 0.2 mg/mL injection. Non-controlled substance. Rx only.
Indications: To increase heart rate from opioids or anesthesia-mediated bradycardia.
Contraindications: Use extreme caution in patients with suspected or known GI obstructions or infections, hyperthyroidism, hypertension, HCM, CHF, or arrhythmias.
Adverse Effects: Minimal side effects, including dry mouth, vomiting, dysphagia, constipation, and thirst. At higher doses, cardiovascular effects are noted, including sinus tachycardia and increased myocardial work and oxygen requirements. Low-doses may induce 2nd degree AV block.
Onset and Duration of Action: Onset: 3-5 min (IV); 10-20 min (IM). Duration: ~60 min. Generally, onset and duration are longer than atropine; glycopyrrolate is thought to be more "gentle" than atropine.
Dosing:

- 0.005-0.02 mg/kg IV or IM

Highlight Blurb:

Glycopyrrolate is an anticholinergic, specifically a synthetic antimuscarinic. In anesthesia and sedation practices, glycopyrrolate is indicated for the prevention or treatment of sinus bradycardia and decreased cardiac output secondary to anesthetics. It is important to note that glycopyrrolate (or atropine) is not recommended to treat dexmedetomidine-induced bradycardia due to increased SVR and potential for undue strain on the heart. Glycopyrrolate is thought to be more "gentle" than atropine, as it does not penetrate the CNS and has a longer onset of action (20-30 minutes) with a longer duration of action (1-2 hours). Glycopyrrolate is contraindicated in patients with confirmed or suspected GI obstructions or constipation, as it slows GI motility. Common side effects include dry secretions, urinary retention, constipation, thirst, and vomiting.

Hydromorphone (*Dilaudid*) C-II

Class: Full-mu agonist opioid
Mechanism of Action: Full mu-opioid receptor (MOR) agonist; potent opioid.
Common Formulation and Controlled Status: Commercially available: 1, 2, 4, and 10 mg/mL injection. Several oral formulations are available but not used in veterinary medicine due to poor bioavailability. DEA Schedule C-II controlled drug. Rx only.
Indications: Analgesia (both rescue and surgical), sedation, surgical premedication, anesthetic induction and maintenance adjunct.
Contraindications: Like other potent opioids, there are few contraindications. Use with caution in patients with hepatic or renal dysfunction, debilitation, and shock. Avoid or use caution with GI obstructions or ileus, as full-mu-agonist opioids slow GI motility. IM administration is known to cause vomiting and panting, while IV administration is associated with less adverse effects. Also, have both human and veterinary naloxone on hand when administering potent opioids to patients.
Adverse Effects: Nausea/vomiting, hypersalivation, mydriasis, hyperthermia (especially in cats), sedation, ataxia, hypoventilation or apnea, diarrhea or constipation, slowed GI motility, vocalization, and hypotension/decreased cardiac output generally due to bradycardia which can be corrected with an anticholinergic.
Onset and Duration of Action: Onset: 30-90 sec (IV); 3-6 min (IM). Duration: ~2-3 hours. Some suggest that IM dosing lasts up to 4 hours, but IV dosing is likely required to repeat every 2 hours.
Dosing:

- 0.1 mg/kg IV or IM for general analgesia
- 0.1 mg/kg IV or IM with a benzodiazepine (0.2 mg/kg), acepromazine (0.02 mg/kg), or dexmedetomidine (3-5 mcg/kg) for sedation or surgical premedication
- 0.05 mg/kg IV for intraoperative analgesia or arousal
- 0.2 mg/kg IV at induction with half-dose induction agent (likely to need mechanical ventilation)
- 0.01-0.05 mg/kg/hr IV CRI for analgesia or PIVA

Highlight Blurb:

Hydromorphone is a full-MOR agonist with a higher potency than morphine but less than fentanyl. Hydromorphone produces profound

analgesia and dose-dependent sedation. Hydromorphone has extensive emetic properties and elicits emesis in almost every healthy, BAR patient. In painful or sedated patients, there's a lower reported incidence of nausea and vomiting. Hydromorphone may be used as an emetic instead of other options such as apomorphine and dexmedetomidine. Due to its strong nauseating effect, patients display ptyalism (hypersalivation), panting, vocalization, and defecation. Hydromorphone should be avoided (or used sparingly) in patients where these effects could be deleterious. A common general practice procedure where hydromorphone should not be used is an enucleation (as panting causes increased IOP). Because of its reliable analgesia and sedation, hydromorphone is widely used preoperatively for preoperative sedation and intraoperative analgesia. Hydromorphone is also useful in a CRI, especially with lidocaine and ketamine. Oral hydromorphone has low bioavailability and is therefore not used in practice. Hydromorphone is well absorbed and can be given IV, IM, or SC. Emesis, delirium, and vocalization are all less likely with IV administration. SC administration has the highest incidence of undesired effects.

Isoflurane (*Isoflo*) and Sevoflurane (*SevoFlo*)

Class*:* Inhalant (Volatile) General Anesthetics
Mechanism of Action: somewhat unknown; thought to be GABA-agonist and inhibitor of voltage gated channels.
Common Formulation and Controlled Status: Commercially available: 99.9%/mL in 100mL or 250mL bottles. Non-controlled substance. Rx only.
Indications: Maintenance of general anesthesia. Isoflurane and sevoflurane are very similar in terms of their physiologic effects. Main difference is sevoflurane has a much quicker onset and offset.
Contraindications: Avoid in patients with malignant hyperthermia. Never use inhalants for induction; inhalant inductions are extremely stressful, require unpredictable and often very high amounts of inhalants, and make for unpredictable maintenance and recovery. Avoid in head trauma as it may cause increased ICP secondary to increased cerebral perfusion. Only use with proper methods of ventilation and airway securement are in place. Never use without proper analgesia.
Adverse Effects: Dose dependent vasodilation and subsequent hypotension that is usually responsive to intravenous fluid boluses but may require use of vasopressors (i.e. norepinephrine). Cardiac-depression occurs as most surgical planes including myocardial depression and decreased heart rate; cats tend to be more sensitive to these effects. Also may cause respiratory depression.
Onset and Duration of Action: Dependent on oxygen flow rate and respiratory rate. Generally, isoflurane takes effect within 1-2 minutes of initiation and sevoflurane 20-40 seconds. Clearance depends on maintenance depth and co-mendicants but sevoflurane is generally within 30-60 seconds and isoflurane is generally 1-2 mins.
Dosing:

Generally, the lowest effective percent is used. MAC (mean alveolar concentration) refers to the percent of isoflurane being delivered in a given gas (i.e. oxygen). Dosing is directly correlated to oxygen flow rates.

Isoflurane: Generally, dogs and cats require anywhere from 0.5-1.5% to maintain general anesthesia when proper analgesia and oxygen rates are used.

Sevoflurane: Generally 2-4% with proper oxygen flow rates and analgesia.

Transition oxygen rates are used for the first 2-5 mins after initiating isoflurane general anesthesia to obtain an adequate surgical plane of

anesthesia and allows for isoflurane to fill a breathing circuit efficiently.

Maintenance oxygen rates are used for maintenance of general anesthesia and are generally lower than transition rates as after the first few minutes of an anesthetic event, the patient generally falls into a steady plane of anesthesia. This also reduces the amount of isoflurane a patient inhales; therefore, a quick increase of oxygen rates and MAC during arousal will quickly deliver more isoflurane to a patient.

Note: Oxygen rates should never be <0.5L/min due to unpredictable vaporizer output.

System	Transition Rate (O_2)	Maintenance Rate (O_2)
Rebreathing (>5-7kg)	0.1-0.15 L/kg/min	0.05 L/kg/min (50mL/kg/min)
Non-Rebreathing (<5-7kg)	0.3 L/kg/min	0.2-0.3 L/kg/min

Ketamine (*Ketase, Vetelar, Ketoflo*) C-III

Class*:* N-methyl-D-aspartate (NMDA)-receptor antagonist, dissociative general anesthetic

Mechanism of Action: Decreases glutamate release and neuronal excitability in the spinal cord and brain.

Common Formulation and Controlled Status: Commercially available: 10, 50, and 100 mg/mL injection. DEA Schedule C-III controlled drug. Rx only.

Indications: Immobilization agent, sedation adjunct, general anesthesia induction agent, analgesic for use as a bolus or CRI/PIVA, chronic pain analgesic, anti-epileptic in refractory status epilepticus (via GABA-reuptake inhibition).

Contraindications: Hypertension, heart failure, DCM/HCM, or any cardiovascular disease where increases in heart rate may be detrimental. Use with caution in hepatic or renal disease. Avoid in cases of unmanaged endocrine disease, especially hyperthyroidism. Ketamine should never be used alone for analgesia, sedation, or analgesia due to its dysphoric effects and muscle rigidity. Ketamine may cause seizures if used alone.

Adverse Effects: Tachycardia, slight hypertension, nausea**/**vomiting, hypersalivation, hyperthermia, sedation, ataxia, violent recovery (if used alone), myoclonus, hypertonicity, and tremors. Seizures occur in about 20% of cats who receive ketamine alone, but the addition of a benzodiazepine or opioid typically reduces the risk of seizures. Lower doses (1-2 mg/kg) provide desired clinical effects with minimal adverse effects. Ketamine is known to cause catecholamine release which stimulates the sympathetic NS; use ketamine sparingly in cases where this may be detrimental.

Onset and Duration of Action: Onset: 30-60 seconds (IV); 3-10 min (IM). Duration: 15-30 min. Duration is dose dependent. Increasing the dose does not increase effects.

Dosing:

- 2-5 mg/kg IV or IM for general anesthesia induction with propofol, midazolam, or other anesthetics.
- 0.3-0.5 mg/kg IV for intraoperative analgesia or arousal
- 2-3 mg/kg IM as a sedation adjunct with other sedatives
- 0.3-1 mg/kg IV or IM for analgesia in conscious patients (consider sedatives to decrease change of dysphoria)
- 0.1-1.5 mg/kg IV CRI for analgesia or PIVA

- Doses >5 mg/kg are occasionally used in some cocktails (i.e., Kitty Magic) and are reported to be safe but generally should be avoided due to risk of increased adverse effects

Highlight Blurb:

Ketamine is an NMDA-receptor (NMDAR) antagonist that decreases the release of glutamate (a primary excitatory neurotransmitter) in the CNS; specifically, there is a high concentration of NMDARs in the hippocampus and the dorsal horn of the spinal cord. This produces dissociation (patient becomes unaware of their senses and surroundings) and analgesia via decreasing excitatory stimuli in the afferent pathways of the spinal cord (dorsal horn). Ketamine provides great visceral and somatic analgesia. Ketamine's primary indication is induction of general anesthesia, sedation, and analgesia. Ketamine has a short duration of action (15-40 min), which is dose-dependent due to the ceiling effect. Ketamine is also indicated as an analgesic CRI. Ketamine causes a transient increase in sympathetic tone, so transient tachycardia, hypertension, and muscle rigidity may be present in healthy patients. However, in critically ill patients, ketamine may cause cardiovascular collapse as ill patients may have exhausted their adrenal cortex. Ketamine is contraindicated in animals with moderate to severe cardiovascular disease, un- or poorly-managed metabolic or endocrine disease, and hepatic insufficiency. Ketamine can be given IV or IM and is best used in combination with other anesthetics and sedatives to decrease side effects. Ketamine may cause dysphoria and/or a violent recovery when used as a single agent.

Lidocaine 2%

Class: Amide Local Anesthetic; Class IB Antiarrhythmic; Prokinetic
Mechanism of Action: Blocks sodium ion channels on membranes of neurons to cause hyperpolarization and decreased neuronal excitability.
Common Formulation and Controlled Status: Commercially available: 0.5% (5 mg/mL), 1% (10 mg/mL), 2% (20 mg/mL), 4% (40 mg/mL) injection. Most commonly used is 2% lidocaine. Various topical creams and solutions are also available. There are also several lidocaine formulations with epinephrine, but these are less commonly used in veterinary medicine. Non-controlled substance. Rx only.
Indications: Local or systemic analgesia, prokinetic, antiarrhythmic, alpha-2 agonist anti-bradycardic, cardio- and renal-protectant.
Contraindications: Severe SA, AV, or ventricular blocks, shock, CHF, and severe bradycardia. Use with caution in cases of hepatic disease (lower doses by 50%) and with cardiorespiratory depression. Intravenous lidocaine should be avoided in cats due to high risk of cardiovascular and CNS depression or death.
Adverse Effects: True adverse effects are very rare at clinically accepted doses. Most notable (and rare) side effects include sedation, ataxia, nausea and vomiting, muscle tremors, and PR, QRS, QT interval changes.
Onset and Duration of Action: Onset: 1-2 min (IV); 5-15 min (local). Duration: 10-20 min (IV); 1-2 hours (local). Duration is dose-dependent. Increasing the dose does not increase effects.
Dosing: IV dosing is for canines only (DO NOT USE IV LIDOCAINE IN CATS)

- 2-4 mg/kg for local tissue infiltration (Canine max dose= 10 mg/kg; Feline max dose= 5 mg/kg)
- 2 mg/kg IV as an antiarrhythmic or dexmedetomidine induced bradycardia
    - Repeat every 3-5 min until effect, max dose= 8 mg/kg IV
- 1-3 mg/kg/hr IV CRI for prokinetic, antiarrhythmic, systemic analgesia, and MAC-sparing

Highlight Blurb:

Lidocaine is a local, amide anesthetic that can be administered intravenously to illicit a CNS effect. Systemic (or intravenous) lidocaine is indicated for systemic analgesia, as a prokinetic, to blunt sympathetic stimulation of intubation, to prevent renal, hepatic, or cardio-toxicity in cases of obstructive shock, as an emergency antiarrhythmic, and to improve

bradycardia secondary to dexmedetomidine. The most common indication for IV lidocaine in general practice anesthesia is to prevent or treat bradycardia secondary to dexmedetomidine, to prevent or treat ventricular arrhythmias or as an analgesic adjunct. Less commonly, lidocaine is useful in GI cases as a prokinetic but most providers prefer metoclopramide due to its selective prokinetic activity. Lidocaine is known to cause seizures and occasionally sedation and vomiting, as well as transient hypotension via vasodilation. Contraindications of systematic lidocaine include feline patients (causes major CV and CNS depression and potentially cardiac arrest if high doses are used).

Maropitant (*Cerenia*)

Class: Neurokin-1 (NK-1) receptor antagonist
Mechanism of Action: Decreases substance-P binding in CNS which decreases neuronal excitable especially in the CRTZ
Common Formulation and Controlled Status: Commercially available: 10 mg/mL injection and 16, 24, 60, 160 mg tablets. Non-controlled substance. Rx only.
Indications: Prevention or treatment of acute vomiting, antitussive, and adjunctive analgesic.
Contraindications: Overall, well tolerated and safe. Use caution in cases of GI obstruction or indiscretion. Does not provide anti-nausea effects, only antiemetic effects. Use caution in hepatic disease.
Adverse Effects: Sedation/lethargy, vasodilation with other vasodilatory agents especially when given IV, anorexia, diarrhea, tremors and convulsions.
Onset and Duration of Action: Onset: 30-60 seconds (IV); 3-10 min (IM). Duration: 15-30 min. Duration is dose dependent. Increasing the dose does not increase effects.
Dosing:

- 2 mg/kg PO for acute prevention or treatment of vomiting (labeled dose, dogs only)
- 5-8 mg/kg PO the night before OR the morning of surgery (anecdotal)
- 8 mg/kg PO for motion sickness (labeled dose, dogs only)
- 1 mg/kg IV or SC 30 min prior to surgical premedication (both dogs and cats)
- 2 mg/kg IV or SC for MAC-sparing/analgesic adjunct

Highlight Blurb:

Maropitant is an NK-1 receptor antagonist that reduces substance-P (excitatory neurotransmitter) binding in the CNS. Maropitant produces an antiemetic effect by reducing activity in the chemoreceptor trigger-zone (CRTZ). Therefore, it is indicated to control or prevent vomiting in cats and dogs related to anesthesia, illness, or motion sickness. It is also indicated as an analgesic adjunct and antitussive. Maropitant has minimal effect on nausea, and it is commonly used with ondansetron for this reason. Use caution in hepatic dysfunction (heavily metabolized by the liver) and with electrical cardiac abnormalities, as QT prolongation is possible. Maropitant is a potent tissue irritant, causing injection site pain. For this reason, maropitant should not be administered IM. Recommended routes of

administration include PO, SC, or IV (IV administration should only be done through an intravenous catheter as extravasation will cause intense pain and stinging). Notable side effects include sedation and vomiting (only when given orally on an empty stomach). The duration of action is 24 hours with a quick onset of action when administered SC (15-30 min) or IV (1-5 min).

Medetomidine/Vatinoxan (*Zenalpha*)

Class: Alpha-2 Adrenergic Receptor Agonist/Alpha-2 Adrenergic Receptor Antagonist

Mechanism of Action: Medetomidine decreases norepinephrine release in the CNS and PNS. Vatinoxan is a peripheral alpha-2 adrenergic receptor antagonist with the primary aim to minimize the effect of peripheral vasoconstriction, systemic hypertension, and bradycardia secondary to medetomidine. Because vantinoxan does not cross the blood-brain barrier, sedation and analgesic effects of medetomidine are expected to remain.

Common Formulation and Controlled Status: Commercially available: 0.5/10 mg/mL injection. Non-controlled substance. Rx only.

Indications: Immobilization and sedation agent. Currently only FDA approved for dogs.

Contraindications: Feline patients (causes profound hypotension), shock, respiratory disease, or severe debilitation. Do not give to those with preexisting hypertension, bradycardia, and/or hypoxemia. Avoid in cardiovascular disease and nervous or hyperactive dogs. Avoid in patients with renal or hepatic dysfunction.

Adverse Effects: Very well tolerated in clinically healthy dogs. Most common side effects (2-4%) are diarrhea and muscle tremors.

Onset and Duration of Action: Onset: 30-60 seconds (IV); 3-10 min (IM). Duration: 15-30 min. Duration is dose-dependent. Increasing the dose does not increase effects.

Dosing: The dose is referring to medetomidine (0.5 mg/mL).

- 0.5-1 mg/m^2 (*not* mg/kg—BSA based, anecdotal weight-based dosing has been reported)
- Please refer to the manufacturers dosing table for more specific weight-based dosing.

Highlight Blurb:

Medetomidine/vatinoxan is a combination medication. Medetomidine (Domitor) is an alpha-2 adrenergic receptor agonist (also called “Alpha-2”) similar to dexmedetomidine. Zenalpha is only approved for use in dogs, and there is little data on its use in cats. Vatinoxan is a peripheral alpha-2 adrenergic receptor antagonist. Vatinoxan does not penetrate the CNS and therefore only prevents adrenergic stimulation in vascular smooth muscle (does not reverse sedation/analgesia). This reduces the incidence of increased SVR, hypertension, and bradycardia. Although it exerts fewer cardiac effects compared to medetomidine/dexmedetomidine,

Zenalpha should still be used sparingly in at-risk animals. Contraindications include shock, hepatic/renal disease, CV disease, arrhythmias, and acute cardiorespiratory abnormalities. Side effects are significantly less than medetomidine/dexmedetomidine alone, limited to lower GI effects (2-4% of dogs) and minimal CV effects. The dose for Zenalpha is body surface area (BSA) based, not weight based. However, anecdotal weight-based dosing has been reported. The labeled dose is 1 mg/m^2 with the anecdotal dosing at 0.01-0.05 mg/kg (10-50 mcg/kg). The larger the patient, the lower the mg/kg dose. For example, a 5 kg dog should receive 40 mcg/kg, while a 40 kg dog should receive 10 mcg/kg. Zenalpha produces ~45 minutes of sedation with an onset of 10-15 minutes. Zenalpha is only approved for intramuscular injection; anecdotal IV dosing has been reported at ½ the IM dose.

Meloxicam (*Metacam*)

Class*:* Non-Steroidal Anti-Inflammatory Drug (NSAID)
Mechanism of Action: Preferential COX-2 inhibition (less than carprofen), which inhibits prostaglandin synthesis. Prostaglandins play a crucial role in the inflammatory cascade by recruiting immune cells and causing increased permeability of capillaries. Prostaglandins also cause chemical insults to peripheral nerves which cause pain.
Common Formulation and Controlled Status: Commercially available: 7.5 and 15 mg tablets 5 and 10 mg capsules, 0.5 and 1.5 mg/mL oral suspension, 5 mg/mL injection. Non-controlled substance. Rx only.
Indications: Perioperative analgesia, osteoarthritis analgesia and management, and acute musculoskeletal pain relief.
Contraindications: History of GI ulceration, acute GI distress, chronic inflammatory syndromes (e.g., IBD), renal or hepatic impairment, bleeding or clotting disorders, and concurrent administration with corticosteroids.
Adverse Effects: The FDA issues a Black Box Warning that repeated meloxicam administration may cause acute kidney failure and even death. However, it is well-tolerated in healthy cats when administered in an acute setting. Dogs seem to tolerate meloxicam very well with the most common side effects including GI upset (vomiting, diarrhea, anorexia), renal and/or hepatic damage, and GI ulceration. Must give the oral formulation with a meal to decrease risk of GI ulceration. Parenteral meloxicam has a lower incidence of GI ulceration/upset due to the bypass of the GI tract.
Onset and Duration of Action: Onset: 2-4 hours (PO or SC). Duration: 24 hours (dose-dependent).
Dosing:

- 0.1-0.2 mg/kg SC for general use in dogs or cats
- 0.1 mg/kg SC for use as a single injection for perioperative analgesia in cats
- 0.1 mg/kg IV for perioperative analgesia in dogs
- Dogs: 0.2 mg/kg SC or PO for acute analgesia followed by 0.1 mg/kg PO q24hr after day 1
- Cats: 0.2 mg/kg SC or PO on day 1 followed by 0.05 mg/kg PO q24hr OR 0.1 mg/kg PO q48hr

Highlight Blurb:

Meloxicam is an NSAID that produces analgesia via inhibiting prostaglandin synthesis. Meloxicam is commonly indicated for intra-operative and postoperative analgesia, as well as acute and chronic

musculoskeletal pain. Meloxicam is only FDA approved for short-term use in cats but is widely used off label at low-doses for long-term pain management in cats. Meloxicam is also used in dogs, but there is some evidence that carprofen may be more effective for canine surgical pain. Meloxicam is contraindicated in patients with hepatic, renal, or inflammatory disease. Meloxicam should be used with caution in patients with GI disorders or those with a history of GI ulceration. Due to prostaglandin inhibition, the gastric lining is reduced and increases the risk of GI ulceration. Therefore, it should also be avoided in animals with hemorrhagic or clotting syndromes. Side effects include GI ulceration, GI distress (vomiting, diarrhea, anorexia), renal/hepatic damage, and pruritus. Meloxicam has a long mechanism of action (~24 hours) with an intermediate onset of action (2.5 hours SC and 2-6 hours PO).

Methadone C-II

Class*:* Full-mu-agonist opioid, weak NMDA-receptor antagonist; weak SNRI

Mechanism of Action: Full mu-opioid-receptor (MOR) agonist; decreases glutamate binding in CNS, which aids in analgesic effects; decreases reuptake of norepinephrine, which aids in analgesic effects.

Common Formulation and Controlled Status: Commercially available: 10 mg/mL injection. 5 and 10 mg tablets. There are other oral formulations that are rarely used in veterinary medicine. DEA Schedule C-II controlled drug. Rx only.

Indications: Analgesia (both rescue and surgical), sedation, and surgical premedication.

Contraindications: Like other potent opioids, there are few contraindications. Use with caution in patients with hepatic or renal dysfunction, debilitated patients, and shock. Avoid or use caution with GI obstructions or ileus as full-mu-agonist opioids slow GI motility. IM administration is known to cause vomiting and panting, while IV administration is associated with fewer adverse effects. Also, have both human and veterinary naloxone on hand when administering potent opioids to patients.

Adverse Effects: Nausea/vomiting, hypersalivation, mydriasis, hyperthermia (especially in cats), sedation, ataxia, hypoventilation or apnea, diarrhea or constipation, slowed GI motility, vocalization, and hypotension/decreased cardiac output in rare cases (usually at higher doses). Bradycardia is more likely with methadone than other opioids but can be treated with anticholinergic therapy.

Onset and Duration of Action: Onset: 30-60 seconds (IV); 10-15 min (IM). Duration: ~2-4 hours. Higher doses may increase dosing interval (e.g., 0.5 mg/kg q6hr).

Dosing:

- 0.2-0.3 mg/kg IM/SC or 0.1-0.2 IV for surgical premedication with other sedatives
- 0.5 mg/kg IV or IM for rescue analgesia q4-6hr
- 0.12 mg/kg/hr IV CRI for analgesia and MAC-sparing
- 0.3 mg/kg IM with other IM sedatives for procedural sedation
- Doses up to 1 mg/kg in dogs have been safe and may last up to 8 hours but produce significant sinus bradycardia that commonly leads to poor hemodynamics.

Highlight Blurb:

Methadone is a full-mu agonist opioid that produces analgesia and sedation. Methadone also antagonizes the NMDA receptor and has some serotonergic activity. These actions aid in methadone's analgesic effects. Methadone is known to have a lower side effect profile than other opioids (e.g., hydromorphone). However, IM administration may still manifest with vomiting and panting but still less than others. Opioids are known to cause slowed GI motility, so avoidance of methadone in patients with GI obstruction or ileus is recommended. Hemodynamic changes are uncommon with methadone, but bradycardia is the most likely change to note. This may be corrected with an anticholinergic such as glycopyrrolate. Methadone should be avoided in patients with severe debilitation, respiratory disease, or hepatic dysfunction. Methadone is an intermediate-duration opioid with an action of ~2-4 hours; some suggest the duration increased with dose. Methadone is generally best given IV or IM but can be given SC or OTM. Oral availability in dogs and cats is low.

Midazolam (Versed) C-IV

Class: Benzodiazepine (GABA agonist)
Mechanism of Action: Agonizes GABA receptors, which allows an influx of chloride ions into the neuron to cause hyperpolarization and decrease excitability. This relaxes various parts of the brain and brainstem to various degrees.
Common Formulation and Controlled Status: Commercially available: 1 and 5 mg/mL injection. Several oral and nasal formulations are available but not used in veterinary medicine due to poor bioavailability. DEA Schedule C-IV controlled drug. Rx only.
Indications: Anxiolysis, sedation, surgical premeditation, anesthetic induction, and muscle relaxation.
Contraindications: Caution should be used in patients with renal or hepatic dysfunction, heart failure, or those who are debilitated. Midazolam should be used cautiously with other respiratory depressants. Do not use with etomidate for ocular surgery as clinically significant increased IOP and meiosis have been reported. Do not administer as a sole agent to BAR, healthy patients as this may cause extreme excitation; use in conjunction with other sedatives.
Adverse Effects: Sedation, ataxia, hypoventilation, or apnea.
Onset and Duration of Action: Onset: 30-60 seconds (IV); 6-10 min (IM). Duration: ~1-3 hours.
Dosing:

- 0.2 mg/kg IM with other sedatives for procedural sedation or surgical premedication
- 0.25 mg/kg IV with ketamine 5 mg/kg to create "Ket:Val"
- 0.5 mg/kg IM for immediate control of seizures or status epilepticus

Highlight Blurb:

Midazolam is a short-acting benzodiazepine that acts at GABA receptors largely located in the hippocampus, thalamus, and brainstem. Midazolam is indicated for sedation, anxiolysis, acute seizure management, and induction. Due to benzodiazepines' action in the depressing brainstem, midazolam produces dose-dependent respiratory depression and apnea. These deleterious effects can be reversed with flumazenil, a benzodiazepine reversal agent (GABA antagonist). Midazolam can cause excitation when used as a single agent in healthy, non-painful, and bright patients. Midazolam is best used in combination with an opioid or ketamine. Midazolam is known to be cardio-sparing. Use caution when administering

with other respiratory depressants. Use caution in clinically significant hepatic or renal disease, debilitated/obtunded patients, or aggressive patients. Midazolam can be given IM or IV; however, it must be given IV slowly to avoid excitation and dysphoria. Midazolam's duration of action is short compared to other benzodiazepines at ~1-3 hours.

Morphine (*DuraMorph*) C-II

Class*:* Full-mu agonist opioid
Mechanism of Action: Full mu-opioid-receptor (MOR) agonist
Common Formulation and Controlled Status: Commercially available: 0.5, 1, 2, 4, 5, 8, 10, 50 mg/mL injection. DEA Schedule C-II controlled drug. Rx only.
Indications: Analgesia (both rescue and surgical), sedation, and surgical premedication. Less preferred than hydromorphone or methadone due to higher side effect profile.
Contraindications: Like other potent opioids, there are few contraindications. Use with caution in patients with hepatic or renal dysfunction, debilitated patients, and shock. Contraindicated in patients who are receiving or have received (within the last 14 days) monoamine oxidase inhibitors (MAOIs). Avoid or use caution with GI obstructions or ileus as full-mu-agonist opioids slow GI motility. Vomiting, hypotension, and histamine release are common side effects of morphine; avoid in cases where these symptoms could be detrimental.
Adverse Effects: Nausea/vomiting, hypersalivation, bradycardia, hypotension, histamine release, mydriasis, hyperthermia (especially in cats), sedation, ataxia, hypoventilation or apnea, diarrhea or constipation, slowed GI motility, vocalization, and decreased cough/gag reflex (increasing risk of aspiration).
Onset and Duration of Action: Onset: 30-60 seconds (IV); 5-10 min (IM). Duration: ~2 hours.
Dosing:
Dog:

- 0.1-0.2 mg/kg IV, IM, SC for general analgesia
- 0.3 mg/kg IV or IM with other sedatives for surgical premedication or procedural sedation
- 0.05-0.2 mg/kg/hr IV CRI for analgesia, PIVA, and MAC-sparing effects

Cat:

- 0.1-0.25 mg/kg IV, IM, SC for general analgesia
- 0.1 mg/kg IV or IM with other sedatives for surgical premedication or procedural sedation
- 0.05-0.1 mg/kg/hr IV CRI for analgesia, PIVA, and MAC-sparing effects

Highlight Blurb:

Morphine is a class opioid agonist (specifically MOR) that produces dose-dependent sedation and analgesia. Morphine is indicated for surgical premedication, rescue analgesia, sedation adjunct, and as a continuous rate infusion. Morphine is slowly being phased out of veterinary practice due to many preferring newer options. Morphine is known as a "dirty drug"—meaning it is not very selective with its effects; morphine is known to cause histamine release (and therefore vasodilation, hypotension, shock, etc.) and has a high GI side effect profile. Morphine also has a very variable response depending on patient mentation, age, health, and species. Most practitioners choose hydromorphone or methadone over morphine due to their more predictable effects. Cats tend to develop excitatory behavior after a morphine injection, unlike dogs. Dogs can also develop physical dependence (if used chronically) and must be weaned off slowly. Respiratory depression was found to be more common with morphine than with hydromorphone or methadone. Morphine may be given orally (although displays poor bioavailability) or by IV, IM, or SC routes. Feline dosing is usually 0.1-0.2 mg/kg q2hr with dogs requiring higher dosing of 0.5-1 mg/kg q2hr.

Ondansetron (*Zofran*)

Class: Anti-nausea, 5HT3-receptor antagonist
Mechanism of Action: Decreases serotonin binding centrally and peripherally to decrease nausea and subsequent vomiting. Ondansetron is not considered to be an antiemetic as it only treats and prevents nausea-mediated vomiting.
Common Formulation and Controlled Status: Commercially available: 2 mg/mL injection, 4 and 8 mg tablets (also available as ODT tablets). Non-controlled substance. Rx only.
Indications: To treat or prevent nausea and vomiting in dogs and cats.
Contraindications: Use with caution in patients with hepatic or renal dysfunction. Use caution with GI obstructions or ileus as ondansetron may slow GI motility. May cause QT prolongation and fatal cardiac arrhythmias (rare in animals); use caution and frequent monitoring in patients with abnormal electrophysiology of the heart (or suspected).
Adverse Effects: Constipation, diarrhea, sedation, headshaking (potentially from a headache; reported in humans), increased liver enzymes, arrhythmias, and hypotension (rare).
Onset and Duration of Action: Onset: 2-3 min (IV); 5-15 min (IM). Duration: ~8-12 hours.
Dosing:

- 0.1-0.5 mg/kg IV or IM q8-12hr (can give SC in cats, not dogs)
- 0.5-1 mg/kg PO q8-12hr

Highlight Blurb:

Ondansetron is a $5HT_3$-receptor antagonist that decreases serotonergic stimulation to the areas involved in controlling emesis such as the vagus nerve and chemoreceptor trigger-zone (CRTZ). Ondansetron is indicated for relieving or preventing nausea and, in some cases, vomiting. Ondansetron typically only prevents vomiting due to nausea and not infectious or mechanical pathologies. Ondansetron also works to slow GI transit time in the large colon. Some use ondansetron as an anti-diarrheal adjunct. Ondansetron causes QT prolongation (leads to arrhythmias), which is not typically a concern in general practice. However, some practitioners avoid ondansetron in patients with cardiac disease altogether to avoid dysrhythmias. Ondansetron is contraindicated in patients with hepatic dysfunction or those with ileus or lower GI obstruction. Ondansetron's duration of action is 8-12 hours in dogs and cats. Ondansetron can be administered PO, IM, or IV in dogs and cats and SC in cats only.

Commercially available ondansetron is formulated as 2 mg/mL with some reference doses being 0.5 mg/kg; a larger patient will require a very large volume. It is best to administer IV in this case to avoid muscular damage from large, hypotonic, injection volume. All IV injections must be given over at least 30 seconds (although gold standard is over 3-5 min) to avoid potential cardiac complications.

Propofol (*Propoflo-28, Diprivan*)

Class: Hypnotic General Anesthetic (GABA-Agonist)
Mechanism of Action: Opens Cl^- channels, which allows Cl^- to rush into neurons, causing hyperpolarization.
Common Formulation and Controlled Status: Commercially available: 10 mg/mL injection. Non-controlled substance. Rx only.
Indications: General anesthesia induction and maintenance, short IV sedation.
Contraindications: Minimal contraindications exist. Propofol provides no analgesia. Propofol causes hypotension and potentially transient reflex tachycardia; avoid in patients where this may be detrimental. High doses of propofol have a high incidence of respiratory depression and apnea; it is recommended to use other CNS depressants prior to propofol, which can decrease dosing requirements by up to 60%. Infuse propofol at 1 mg/kg over 20 seconds (roughly equal to the entire dose over 1-2 minutes) and titrate until effect; do not give the entire dose if desired effect is reached. Propofol can only be given IV.
Adverse Effects: Transient respiratory depression, apnea (at higher doses), myocardial depression, hypotension, histamine release (uncommon), increased IOP, and prolonged recovery if repeated doses or high-dose CRI is used.
Onset and Duration of Action: Onset: 30-60 sec (IV). Duration: 3-8 min.
Dosing:

- 6 mg/kg IV until effect with 1 mg/kg IV over 30-60 seconds at a time for induction of general anesthesia
- 0.1-0.5 mg/kg/min IV CRI for total intravenous anesthesia (TIVA) or low-doses for balances anesthesia

Highlight Blurb:

Propofol is an injectable general-hypnotic anesthetic that produces hypnosis via GABA-agonism. Propofol is indicated for induction and maintenance of general anesthesia as well as for quick IV sedation. Propofol can be used as a CRI or bolus maintenance or sedation drug. Propofol induction requirements can greatly be reduced by administering proper pre-medications (specifically, dexmedetomidine, acepromazine, and ketamine; concurrent administration may be advantageous due to ketamines sympathetic stimulation, which is thought to reduce hemodynamic depression from propofol). Propofol produces systemic arterial-dilation and subsequent hypotension. Because of propofol's

extensive action in the brainstem, repository depression and/or apnea are common. To avoid hypoventilation, most recommend giving the total dose over 1-2 min (1/2 dose over 30-60 seconds) and only until effect (usually until loose enough jaw tone to facilitate intubation). Propofol does not provide analgesia and cannot be given IM (IV only). There are no complete contraindications to propofol, but caution is advised with renal or hepatic dysfunction and cardiovascular disease. Propofol's duration of action is 3-8 minutes but can be increased by administering other sedatives and anesthetics.

Robenacoxib (*Onsior*)

Class*:* Non-Steroidal Anti-Inflammatory Drug (NSAID)
Mechanism of Action: Selective COX-2 inhibition (much more so than carprofen or meloxicam), which inhibits prostaglandin synthesis. Prostaglandins play a crucial role in the inflammatory cascade by recruiting immune cells and causing increased permeability of capillaries. Prostaglandins also cause chemical insults to peripheral nerves which causes pain.
Common Formulation and Controlled Status: Commercially available: 6, 10, 20, 40 mg tablets; 20 mg/mL injection. Non-controlled substance. Rx only.
Indications: Perioperative analgesia, osteoarthritis analgesia and management, and acute musculoskeletal pain relief in dogs and cats. Especially preferred in feline patients due to lower incidence of side effects in cats when compared to other NSAIDs. Not labeled for more than 3 consecutive days of use in the US, but other countries have proven efficacy and safety for long-term use.
Contraindications: History of GI ulceration, acute GI distress, chronic inflammatory syndromes (e.g., IBD), and renal or hepatic impairment. Use caution in patients with dehydration or hypovolemia.
Adverse Effects: Well-tolerated in healthy patients when administered appropriately. Most common side effects include GI upset (vomiting, diarrhea, anorexia), renal and/or hepatic damage, and GI ulceration. Must give the oral formulation with a meal to decrease risk of GI ulceration.
Onset and Duration of Action: Onset: 2-4 hours (PO or SC). Duration: 24 hours.
Dosing:

- 2 mg/kg SC for general NSAID use in dogs or cats
- Dogs: 1-2 mg/kg PO q24h
- Cats: 1-2.4 mg/kg PO q24h

Highlight Blurb:

Robenacoxib is a more novel NSAID that produces analgesia via inhibiting prostaglandin synthesis. Robenacoxib is a selective COX-2 inhibitor, which significantly decreases risk of GI ulceration and other adverse effects due to minimal COX-1 inhibition. Robenacoxib is commonly indicated for intraoperative and postoperative analgesia, as well as acute and chronic musculoskeletal pain in both dogs and cats. Robenacoxib is only FDA-approved for 3 days use in dogs and cats but is

widely used off label at low-doses for long-term pain management in cats. Carprofen and meloxicam may be better options in canine patients as they provide more analgesia. Robenacoxib is contraindicated in patients with hepatic, renal, or inflammatory disease. Robenacoxib should be used with caution in patients with GI disorders or those with a history of GI ulceration. Due to prostaglandin inhibition, the gastric lining is reduced and increases the risk of GI ulceration (less so than other NSAIDs due to selective COX-2 inhibition). Therefore, it should also be used with caution or avoided in animals with hemorrhagic or clotting syndromes. Side effects include GI ulceration, GI distress (vomiting, diarrhea, anorexia), and renal/hepatic damage but tend to be more rare than other NSAIDs. Robenacoxib has a similar mechanism of action (~24 hours) to other NSAIDs with an intermediate onset of action (2.5 hours SC and 2-6 hours PO).

Tiletamine/Zolazepam (*Telazol*) C-III

Class*:* N-methyl-D-aspartate (NMDA)-receptor antagonist; dissociative general anesthetic/benzodiazepine (GABA-agonist)
Mechanism of Action: Tiletamine decreases glutamate release and neuronal excitability in the spinal cord and brain, which induces dissociation and zolazepam is a GABA-agonist benzodiazepine which opens Cl^- channels in neurons to cause hyperpolarization.
Common Formulation and Controlled Status: Commercially available: 50 mg/mL of both tiletamine/zolazepam injection. 100 mg/mL total; use this concentration for calculations. DEA Schedule C-III controlled drug. Rx only.
Indications: Induction of general anesthesia and immobilization agent.
Contraindications: Pancreatic disease, severe cardiopulmonary disease, and when using a single agent for general anesthesia. Considered to be a safer alternative than ketamine/midazolam or diazepam. *Do not* use with ketamine or other benzodiazepines.
Adverse Effects: Transient tachycardia, pain at injection site, prolonged recovery if given SC or IM, hypoventilation, transient apnea, erratic or violent recovery if used alone, hypersalivation (responsive to atropine), hypertension, hypotension, pulmonary edema, and seizure activity.
Onset and Duration of Action: Onset: 30-60 sec (IV); 5-10 min (IM). Duration: 25-35 min (up to 1hr in cats). Duration is dose-dependent. Increasing the dose does not increase effects but increases duration.
Dosing: Use 100 mg/mL concentration for calculations.

- 2-3 mg/kg IV until effect for induction of general anesthesia with premedication
    - Cats may require up to 5 mg/kg for induction of anesthesia
- 1-2 mg/kg IM or IV with other sedatives for procedural sedation

Highlight Blurb:

Tiletamine/zolazepam is a combination medication primarily indicated for induction of general anesthesia and procedural sedation in dogs and cats. This combination is very similar to ketamine/midazolam (or diazepam). In addition to dissociation (titletamine's anesthetic action), tiletamine is an NMDA-receptor antagonist that produces mild to moderate analgesia. Tiletamine is very similar to ketamine in both its analgesic and anesthetic actions. Zolazepam is a benzodiazepine with similar action to midazolam. The dissociative/benzodiazepine combination is a common one, as dissociatives alone can cause serious side effects (see Ketamine's

Mini Monograph). Tiletamine/zolazepam has few contraindications that generally follow that of other benzodiazepines and dissociative anesthetics. Cats tend to require higher doses to achieve the same effect as dogs. The combination is best used with an opioid and potentially an alpha-2 agonist to increase duration and further decrease the needed dose.

Tramadol (*Ultram*) C-IV

Class: Weak mu-opioid agonist, SNRI properties
Mechanism of Action: Weakly agonizes the mu-opioid receptor and inhibits serotonin and norepinephrine, which aids in its analgesic effects.
Common Formulation and Controlled Status: Commercially available: 50 mg tablets, 5 mg/mL oral solution. DEA Schedule C-IV controlled drug. Rx only.
Indications: Postoperative analgesia with other analgesics, acute or chronic musculoskeletal analgesia, commonly used in palliative care. *Tramadol may not be effective when used alone for pain in DOGS.* In cats, tramadol has increased efficacy.
Contraindications: Minimal contraindications exist. Use caution in patients receiving other CNS or repository depressants or drugs that lower the seizure threshold, in patients with a history of seizures, geriatric or debilitated patients, and patients with hepatic disease. *Do not* use with ondansetron, as it may reverse some of tramadol's serotonin/ norepinephrine-mediated analgesia.
Adverse Effects: Fewer than other opioids. Overall, minimal side effects and very well tolerated in cats and dogs. Most common adverse effects reported include CNS depression or excitement, anxiety, muscle tremors, anorexia, vomiting, diarrhea, hypersalivation, mydriasis, and occasional dysphoria.
Onset and Duration of Action: Onset: 1-3 hours (PO). Duration: 8-12 hours (PO).
Dosing: Most effective in dogs when used with: NSAID + Gabapentin +/- Amantadine

- Dogs: 5-10 mg/kg PO q8h for postoperative analgesia or chronic pain
- Cats: 2 mg/kg PO q8-12h for postoperative analgesia

Highlight Blurb:

Tramadol is a weak mu-opioid agonist and a weak serotonin/ norepinephrine reuptake inhibitor. Tramadol is indicated for postoperative analgesia and as part of a multimodal analgesia protocol for acute or chronic conditions. Tramadol's efficacy may be poor in dogs, especially when used alone. Data is more clear in cats and supports tramadol's analgesic effects. In dogs, tramadol is best used with NSAIDs, gabapentin, and/or amantadine. In cats, tramadol may be adequate alone, but some clinicians suggest still using an NSAID or gabapentin in addition. Tramadol is overall very safe and very well tolerated in both dogs and cats.

There are minimal contraindications and adverse effects. Ondansetron may reverse some of tramadol's serotonin/norepinephrine-mediated analgesia. Tramadol may also have weak alpha-2 adrenergic agonist properties; yohimbine, a classic alpha-2 adrenergic receptor antagonist, has proven to reverse some of tramadol's analgesia.

Chapter 5
Anesthesia and Sedation Protocol

The following protocols are those the authors and contributors agree are everyday, general practice protocols. Importantly, treat the patient, not the protocols; adjustments to dose, dosing intervals, or even drugs may be made based on patient status.

Disclaimer: These protocols are widely accepted combinations and doses. There are dozens more combinations possible and used in practice everyday. These protocols are not extensive listings and should never solely inform clinical judgment. Please refer to more extensive anesthesia references for clinical guidance.

All data dosing, mechanisms, uses, and contraindications provided by Plumb's Veterinary Drug Handbook, 2024, unless otherwise denoted.

The following prehospital protocol is used by the author of this book for each of the following protocols.

Prehospital: to be given orally at home 2-3 hours prior to arrival

- Gabapentin 10-15 mg/kg PO
- Trazodone 3-5 mg/kg PO (dogs only)
- Maropitant 4-6 mg/kg PO (dogs only)
- Omeprazole 1 mg/kg PO (dogs only)

Cats should receive maropitant 1 mg/kg SC at arrival.

Procedures and Anticipated Pain Levels

Procedure	Anticipated Pain Level	Suggested Analgesics
Castration	Mild/Moderate	NSAID, intratesticular block, moderate opioid, ketamine
Ovariohysterectomy	Moderate/Severe	NSAID, splash block, strong opioid, Cerenia, ketamine
Dental (without extractions)	Mild	NSAID, weak to moderate opioid
Dental (with simple extractions)	Mild/Moderate	NSAID, weak to strong opioid
Dental (with surgical extractions)	Moderate/Severe	NSAID, Cerenia, nerve block, strong opioid, +/- opioid/lidocaine/ketamine CRI
Cutaneous Mass Removal	Mild/Moderate	NSAID, local block, weak to strong opioid
Deep Mass Removal	Moderate	NSAID, Cerenia, local block, strong opioid
Laparotomy/enterotomy	Moderate/Severe	NSAID, Cerenia, splash block, strong opioid
Enucleation	Moderate/Severe	NSAID, Cerenia, strong opioid, local block +/- opioid/lidocaine/ketamine CRI
Cesarean Section	Severe	NSAID, Cerenia, line block, splash block, buprenorphine.
CCL Repair	Severe	LS or SC epidural, Cerenia, opioid/lidocaine/ketamine CRI, Alpha-2 agonist, +/- NSAID
Misc. Orthopedic Procedure	Moderate/Severe	LS epidural (pelvic limb), Cerenia, strong opioid, Alpha-2 agonist +/- opioid/lidocaine/ketamine CRI, gabapentin, +/- NSAID

Anesthesia Protocols

Stage	ASA I	ASA II	ASA III	ASA IV	ASA V
Pre-Hospital 2-3 hours prior to admit	Cerenia (maropitant) Gabapentin +/- Trazodone	Cerenia (maropitant) Gabapentin +/- Trazodone	Cerenia (maropitant) Gabapentin +/- Trazodone	Cerenia (maropitant) Gabapentin +/- Trazodone	Cerenia (maropitant) Gabapentin +/- Trazodone
Premedication	Opioid + $Alpha_2$ agonist	Opioid + *One of the following* $Alpha_2$ agonist Acepromazine	Opioid + *One of the following* Microdose $Alpha_2$ agonist Benzodiazepine	Opioid +/- Benzodiazepine	Opioid +/- Benzodiazepine
Induction	Ketamine + *One of the following* Propofol Midazolam	Propofol + *One of the following* Ketamine Midazolam	Propofol + *One of the following* Lidocaine Midazolam	Propofol, Etomidate or Alfaxalone	Propofol, Etomidate or Alfaxalone
Maintenance	Lowest Effective Percent of Inhalant Agent	Lowest Effective Percent of Inhalant Agent	Lowest Effective Percent of Inhalant Agent	Lowest Effective Percent of Inhalant Agent Or Propofol infusion	Lowest Effective Percent of Inhalant Agent Or Propofol infusion
Rescue Analgesia Choose one	Ketamine 0.5 mg/kg Hydromorphone 0.05 mg/kg Methadone 0.2 mg/kg Fentanyl 2-4 mcg/kg	Ketamine 0.3 mg/kg Hydromorphone 0.05 mg/kg Methadone 0.2 mg/kg Fentanyl 2-4 mcg/kg	Ketamine 0.1 mg/kg Hydromorphone 0.05 mg/kg Methadone 0.2 mg/kg Fentanyl 2-4 mcg/kg	Fentanyl 2-5 mcg/kg	Fentanyl 2-5 mcg/kg
Sudden Arousal Choose one	Ketamine 1 mg/kg Propofol 0.5 mg/kg	Ketamine 1 mg/kg Propofol 0.5 mg/kg	Ketamine 1 mg/kg Propofol 0.5 mg/kg	Propofol, Etomidate or Alfaxalone	Propofol, Etomidate or Alfaxalone
MAC-Sparing	NSAID +/- Local Block +/- Dexmedetomidine CRI or opioid/L/K CRI	NSAID +/- Local Block +/- Dexmedetomidine CRI or opioid/L/K CRI	NSAID +/- Local Block +/- Dexmedetomidine CRI or opioid/L/K CRI	Local Block +/- opioid/L/K CRI +/- NSAID	Local Block +/- opioid/L/K CRI +/- NSAID
Postoperative Choose one	Hydromorphone 0.1mg/kg IV q2h Methadone 0.2 mg/kg IV q4h Buprenorphine 0.02 mg/kg IV q4-6h Opioid/L/K CRI	Hydromorphone 0.1mg/kg IV q2h Methadone 0.2 mg/kg IV q4h Buprenorphine 0.02 mg/kg IV q4-6h Opioid/L/K CRI	Hydromorphone 0.1mg/kg IV q2h Methadone 0.2 mg/kg IV q4h Buprenorphine 0.02 mg/kg IV q4-6h Opioid/L/K CRI	Hydromorphone 0.1mg/kg IV q2h Methadone 0.2 mg/kg IV q4h Buprenorphine 0.02 mg/kg IV q4-6h Opioid/L/K CRI	Hydromorphone 0.1mg/kg IV q2h Methadone 0.2 mg/kg IV q4h Buprenorphine 0.02 mg/kg IV q4-6h Opioid/L/K CRI
TGH	NSAID Gabapentin +/- Oral Opioid +/- Trazodone	NSAID Gabapentin +/- Oral Opioid +/- Trazodone	NSAID Gabapentin +/- Oral Opioid	Gabapentin Oral Opioid +/- NSAID +/- Amantadine	NSAID Gabapentin +/- Oral Opioid +/- Amantadine

Sample Canine & Feline Spay/Neuter Protocol

Indications: *ASA I & II patients undergoing castration or ovariohysterectomy*
Contraindications: *ASA III and above patients.*
Notes: *This plan assumes 12-24 hour hospitalization.*

Premedication:

- Methadone 0.2 mg/kg IM
- Dexmedetomidine 2-4 mcg/kg IM (dose is demeanor dependent)

Induction: give in order

- Ketamine 1 mg/kg IV
- Propofol 1 mg/kg IV over 60 seconds, then, titrate until effect (generally no more than 2 mg/kg is required)

Locoregional Anesthesia:

Neuter:

- Lidocaine 2 mg/kg intratesticular 10 minutes prior to incision

Spay:

- Bupivacaine 1 mg/kg pre-incisional line block, ventral midline 30 minutes prior to incision
- Bupivacaine 1 mg/kg intraoperative splash block dripped onto the ovarian pedicles and uterine stump

Maintenance:

- Lowest effective percent of inhalant anesthetic
- Crystalloid fluid at 5 mL/kg/hr with 5mL/kg boluses over 10 minutes for hypotension
- Ketamine 0.5 mg/kg IV for rescue analgesia or sudden arousal
- Dexmedetomidine 0.5-2 mcg/kg over 5 minutes for MAC-sparing

Postoperative:

- Dogs: Carprofen 2.2 mg/kg SC every 12 hours with first dose given at extubation
- Cats: Robenacoxib 2 mg/kg SC every 24 hours with first dose given at extubation
- Buprenorphine 0.02 mg/kg IV every 4-6 hours as needed for pain (give at least 1 dose)
- Gabapentin 10-15 mg/kg PO every 8-12 hours as an analgesic adjunct
- Continue maintenance fluids and encourage oral intake as soon as possible.

To Go Home:

- Dogs: Carprofen 2.2 mg/kg PO every 12 hours for 10 days

- Cats: Robenacoxib 2 mg/kg PO every 24 hours for 3-6 days
- Cats: Simbadol 0.15 mg/kg SC (lower than label dose, authors anecdotally prefer this dose)
- Gabapentin 10-15 mg/kg PO every 8-12 hours as needed for calming/mild pain (dogs and cats)
- Trazodone 3-5 mg/kg PO every 8-12 hours as needed for recovery sedation (dogs only)

Sample Orthopedic Protocol

Indications: *ASA I & II patients undergoing orthopedic procedures such as a TPLO.*

Contraindications: *ASA III and above patients.*

Notes: *This plan assumes 12-24 hour hospitalization.*

Premedication:

- Methadone 0.25 mg/kg IM or IV over 60 seconds
- Dexmedetomidine 1-5 mcg/kg IM or IV over 60 seconds

Induction: give in order

- Ketamine 1-2 mg/kg IV
- Propofol 1-3 mg/kg IV, give each 1 mg/kg over 30 seconds and titrate until effect

Locoregional Anesthesia: to be performed 20-30 minutes prior to incision

- Bupivacaine 1 mg/kg diluted to equal parts NaCl 0.9% for indicated nerve block (e.g. epidural, femoral, sciatic, etc.)
- Dexmedetomidine 0.1 mcg/kg mixed with the bupivacaine solution.

Maintenance:

- Lowest effective percent of inhalant anesthetic
- Crystalloid fluid at 5 mL/kg/hr with 5mL/kg boluses over 10 minutes for hypotension
- If no locoregional anesthesia is performed:
    - Ketamine CRI at 10-20 mcg/kg/MIN
    - Dexmedetomidine 0.5-2 mcg/kg/HOUR

As Needed:

- Ketamine 0.5 mg/kg IV for rescue analgesia
- Propofol 1 mg/kg IV for sudden arousal
- Dexmedetomidine 0.5-2 mcg/kg over 5 minutes for MAC-sparing

Postoperative:

- Continue or start ketamine/dexmedetomidine CRI's for 6-8 hours postoperatively
- Methadone 0.2 mg/kg IV every 4-6 hours for pain
- Wean down to buprenorphine 0.02 mg/kg IV every 4-6 hours for pain
- Dogs: Carprofen 2.2 mg/kg SC every 12 hours for pain with first dose

given in recovery
- Cats Robenacoxib 2 mg/kg SC every 24 hours for pain with first dose given in recovery
- Gabapentin 10-15 mg/kg PO every 8-12 hours as an analgesic adjunct
- Continue maintenance fluids and encourage oral intake as soon as possible.

To Go Home:

- Carprofen 2.2 mg/kg PO every 12 hours for 10-30 days
- Tramadol 2 mg/kg in cats or 5-10 mg/kg in dogs PO every 8-12 hours for pain for 5 days
- Gabapentin 10-15 mg/kg PO every 8-12 hours as needed for breakthrough pain
- Trazodone 3-5 mg/kg PO every 8-12 hours as needed for recovery sedation

Procedural Sedation Cocktails

Use the two tables below to select an appropriate cocktail for your patient. The first table are the most common procedural sedation cocktails and the second table is an algorithm table that allows you to individually select analgesia and sedation levels.

Sedation Cocktails (Canine/ Feline)			
Drug(s)	**Indications**	**Contraindications/ Notes**	**Example Combination**
Benzodiazepine + Opioid	Anxiolysis, light to moderate sedation in old or sick animals.	Very safe combination. If IV, give opioid first to avoid excitation. Avoid if young, healthy and BAR.	Butorphanol 0.3 mg/kg Midazolam 0.2 mg/kg
Acepromazine + Opioid	Deep sedation, moderate analgesia. Long duration.	Avoid in cardiovascular disease.	Acepromazine 0.01 mg/kg Butorphanol 0.3 mg/kg
Dexmedetomidine + Opioid	Moderate sedation, mild/moderate analgesia.	Avoid in cardiovascular disease.	Dexmedetomidine 5 mcg/kg Butorphanol 0.3 mg/kg
Telazol + Opioid + Dexmedetomidine	IM induction for general anesthesia.	Do not reverse within 20 minutes of administration to avoid dysphoria secondary to Telazol.	Telazol 2-4 mg/kg Methadone 0.2 mg/kg Dexmedetomidine 5 mcg/kg
"Kitty/Doggie Magic" Dexmedetomidine + Ketamine + Opioid	Heavy sedation with moderate analgesia. Moderate duration. May need to intubate.	Avoid in cardiovascular disease.	Dexmedetomidine 5 mcg/kg Ketamine 2 mg/kg Butorphanol 0.2 mg/kg
"Cardio-safe Magic" Alfaxalone + Benzodiazepine + Opioid	Opioid dependent analgesia, deep sedation. May need to intubate.	Regarded as a very safe sedation cocktail in cases of shock, trauma, or heart disease.	Alfaxalone 1-2 mg/kg Midazolam 0.2 mg/kg Butorphanol 0.2 mg/kg
Alfaxalone + Sedative	Quick procedural sedation (i.e. radiographs or small laceration repair) .	Very safe combination, may need to be intubated. Avoid dexmedetomidine and use caution with acepromazine in cases of cardiovascular disease.	Alfaxalone 1-2 mg/kg *With one of the following* Midazolam 0.2 mg/kg OR Acepromazine 0.02 mg/kg OR Dexmedetomidine 2-3 mcg/kg
Pre-Euthanasia Cocktail Butorphanol + Acepromazine + Dexmedetomidine +/- Ketamine	For pre-euthanasia sedation. Subcutaneous administration is preferred due to gentle injection and absorption.	Do not use for any other purpose than pre-euthansaia sedation. Addition of ketamine produces general anesthesia. Acepromazine should NEVER be used at this high of a dose in any other case beside euthanasia.	Butorphanol 0.22 mg/kg Acepromazine 0.1 mg/kg Dexmedetomidine 2.2 mcg/kg +/- Ketamine 2.2 mg/kg + 0.1-1mL Vitamin B12 injection or LRS or Sodium Bicarbonate to reduce singing.

Note: Butorphanol is not considered to provide adequate procedural analgesia and should be substituted for a full-mu agonist (such as hydromorphone, morphine, or methadone) in painful cases.

Sedation cocktails for ASA I and ASA II

	Level of Sedation		
Level of Analgesia	**Mild**	**Moderate**	**Deep**
Mild	Butorphanol 0.2 mg/kg IV or IM	Butorphanol 0.2 mg/kg IV or IM Acepromazine 0.01 mg/kg IV or IM	Butorphanol 0.2 mg/kg IV or IM Dexmedetomidine 5 mcg/kg IV or IM Ketamine 2 mg/kg IV or IM
Moderate	Buprenorphine 0.02 mg/kg IV or IM	Buprenorphine 0.02 mg/kg IV or IM Dexmedetomidine 1 mcg/kg	Buprenorphine 0.02 mg/kg IV or IM Dexmedetomidine 5 mcg/kg IV or IM Ketamine 2 mg/kg IV or IM
Profound	Methadone 0.2 mg/kg IV or IM	Methadone 0.2 mg/kg IV or IM Dexmedetomidine 1 mcg/kg	Methadone 0.2 mg/kg IV or IM Dexmedetomidine 5 mcg/kg IV or IM Ketamine 2 mg/kg IV or IM

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An integrated approach to the theory and practice of anesthesia, analgesia, sedation, and physiological principles in small animal general practice.

Benjamin Pritzker is a veterinary anesthesia technician, researcher, and aspiring veterinarian with years of hands-on experience in both general and specialty practice settings. Known for his leadership as Lead Anesthesia Technician at a mixed animal hospital in New Jersey, Benjamin has managed hundreds of anesthetic cases—ranging from routine procedures to high-risk, multidisciplinary surgeries. His clinical focus lies in the intersection of physiology, pharmacology, and pain management, with a special interest in high-quality anesthesia.

He has conducted neuropharmacology research on opioid and dopamine pathways, completed externships at specialty and emergency hospitals, and presented his work in academic and professional settings. Driven by a passion for education and clinical excellence, he wrote Beginner's Guide to Small Animal Anesthesia, Sedation, & Analgesia in General Practice to bridge the gap between foundational theory and practical application for veterinary professionals at every level.
Benjamin plans to specialize in veterinary anesthesia and continue advocating for improved standards in pain management, client education, and interdisciplinary collaboration in veterinary care.

"There are no safe anesthetic agents, there are no safe anesthetic procedures. There are only safe anesthetists."
— Robert M. Smith, MD, pioneer of pediatric anesthesiology